JOURNAL OF THE AERONAUTICAL SCIENCES

VOLUME 4 SEPTEMBER, 1937 NUMBER 11

CONTENTS

Precise Formulas for Unsymmetrical Vee Struts Under Bending and Torsion	E. J. MAILLOUX	443
Cooling of a Radial Engine in Flight	OSCAR W. SCHEY AND BENJAMIN PINKEL	448
Two New Longitudinal Stability Constants	ALEXANDER KLEMIN AND J. G. BEERER, JR.	453
New Airplane Performance Slide Rule	W. C. ROCKEFELLER	460
Speculations on Propellers for Stratosphere Airplanes	SHATSWELL OBER	463
The Variation of Stress in a Tension-Field Beam	H. W. SIBERT	467
Wing Loading	WILBUR C. NELSON	469
Flight Test Research on a Small Bi-Motor Airplane	CLARENCE L. JOHNSON	473
Institute Meeting at the National Air Races		478
Institute Notes		480
Aeronautical Reviews		481

Book Reviews

Armada of the Air, (*Norman Bentley*)		459
Navy Wings, (*Lieutenant Harold Blaine Miller*)		462
Aircraft Materials and Processes, (*George F. Titterton*)	Reid B. Gray	462

Published by the

INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.

JOURNAL OF THE AERONAUTICAL SCIENCES

VOL. 4 SEPTEMBER, 1937 NO. 11

Editor: J. C. HUNSAKER, *Massachusetts Institute of Technology*

PUBLISHED MONTHLY BY THE INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.
AT 20TH AND NORTHAMPTON STS., EASTON, PA.

The JOURNAL OF THE AERONAUTICAL SCIENCES is the official publication of the Institute of the Aeronautical Sciences, Inc., and prints papers of scientific and technical interest to members and subscribers. In general, it provides an opportunity for members to publish articles disclosing new knowledge and new applications in the field of the aeronautical sciences. The Journal prints a few complete professional papers in each issue and a large number of short notes and critical comments. The Journal restricts itself to the aeronautical aspects of advances in science and engineering. New knowledge in physics, metallurgy, meteorology, etc., having aeronautical applications is reported and discussed in the Journal. Papers read at meetings of the Institute are presented in full or digested. Reviews of aeronautical literature and a digest of current aircraft books and magazines form a section of the publication. The news of the Institute is furnished members through the Journal.

SUBSCRIPTION RATES

United States and Possessions		Foreign Countries, Including Canada	
1 Year	$5.00	1 Year	$6.00
Single Copies	.50	Single Copies	.60

Manuscripts for publication, proofs, and all correspondence should be addressed to the Editorial Secretary of the JOURNAL.

Correspondence regarding subscriptions may be addressed to Publication Office, 20th and Northampton Sts., Easton, Pa., or to the Editorial Office of the JOURNAL OF THE AERONAUTICAL SCIENCES, 30 Rockefeller Plaza, Rockefeller Center, New York, New York. Cable Address: INSAEROSCI.

Entered as Second Class Matter at the Post Office, Easton, Pa., May 1, 1937. Acceptance for mailing at a special rate of postage provided for in the Act of August 24, 1912. Authorized April, 29, 1937.

JOURNAL OF THE AERONAUTICAL SCIENCES

Volume 4 SEPTEMBER, 1937 Number 11

Precise Formulas for Unsymmetrical Vee Struts Under Bending and Torsion

E. J. MAILLOUX, *Chance Vought Aircraft*

(Received January 23, 1937)

Introduction

TWO members terminating at a common point, and resisting at the intersection a moment applied in a plane other than the plane of the members, occur frequently in the design of airplane structures.

As a general rule the members are fastened together in some manner and must rotate together at the joint. Although the joint is usually free to rotate it is also usually supported so that there are shearing forces in the members. Fig. 1 shows an unsupported joint while Fig. 2 shows one of the supported type. The former type occurs rarely and is not considered in this paper.

The applied moment can always be resolved into two components, one of which lies in the plane of the members and the other in some particular plane normal to the plane of the members. Appendix B shows how the applied moment is resolved into components by the system of vectorial representation of couples and how the angle between the plane normal to the plane of the members and one of the members is obtained.

The method of distributing the component of moment that lies in the plane of the members, between the members, is generally well known and consists essentially in dividing the moment between the members (producing bending only) so that the slopes of the members are equal at the joint.

This paper deals only with the component of applied moment that lies in a plane normal to the plane of the members and all applied moments referred to or used from now on (except in Appendix B) are in a plane normal to the plane of the members.

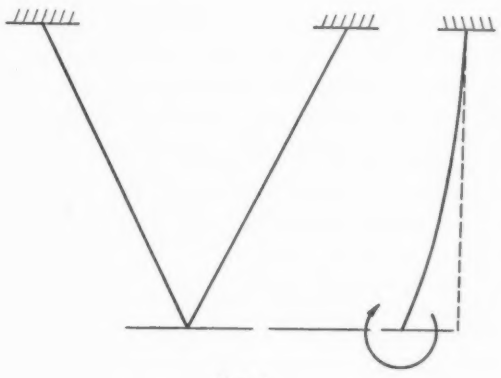

Fig. 1.

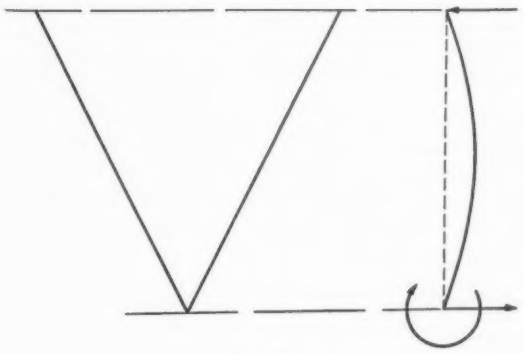

Fig. 2.

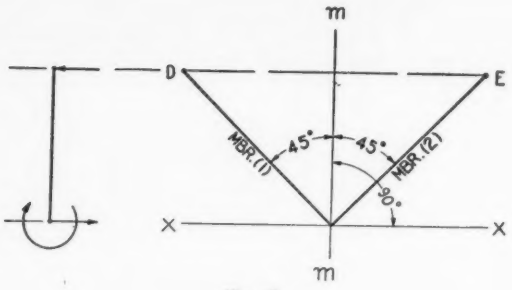

FIG. 3.

In Fig. 3 let such a moment be applied in the plane of m–m. The members are in the plane of the paper and plane of the moment is, of course, normal to the plane of the paper. Axis x–x then is the axis of the applied moment. If the joint is assumed to rotate about axis x–x the bending and torsional moments in the members can be determined by equating the slopes of the members about axis x–x. If one of the members is stiffer than the other it must resist the greater part of the moment to produce equal slopes. It becomes obvious by inspection of Fig. 3 (since the angles shown are equal) that the sum of the components of the bending and torsional moments about axis m–m will not equal zero when the bending and torsional moments in one member are greater than in the other member. In this case then the joint must rotate about an axis other than the axis of the applied moment.

Let the principal axis be defined as the axis about which the joint rotates when a moment is applied to the joint in a plane normal to this axis. A simple formula is derived in this paper for locating the principal axis of any number of members in the same plane. As will be shown there are always two principal axes at right angles to each other. Both are in the plane of the members and pass through the center of the joint. The principal axes also are the axes about which a maximum and a minimum amount of rotation occurs.

For precise solutions the applied moment must be divided into components that are in planes which contain the principal axes.

General Formula for Principal Axis

For one member: (see Appendix A for derivation)

$$(A - B)(\sin 2\alpha \cos 2\beta - \cos 2\alpha \sin 2\beta) = 0 \quad (1)$$

where α and β are the angles shown in Fig. 4, A is the stiffness factor in bending, and B is the stiffness factor in torsion. A and B are usually expressed in terms of the amount of moment necessary to produce a slope or a twist of 1 radian at the end of the member.

For two members:

$$(A_1 - B_1)(\sin 2\alpha_1 \cos 2\beta - \cos 2\alpha_1 \sin 2\beta) + (A_2 - B_2)(\sin 2\alpha_2 \cos 2\beta - \cos 2\alpha_2 \sin 2\beta) = 0$$

The formula can be increased in like manner for additional members in the same plane.

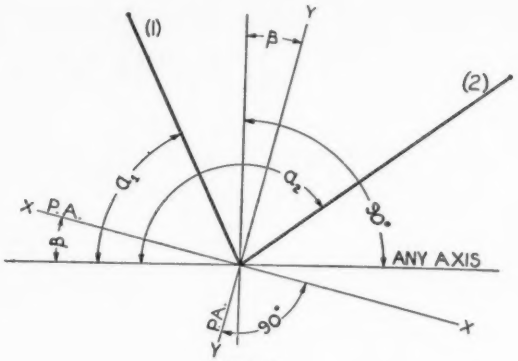

FIG. 4.

The numerical values are substituted and the equation is solved for β. Care must be taken to use the proper signs for $\sin 2\alpha$ and $\cos 2\alpha$, *e.g.*, if $\alpha = 120°$, $2\alpha = 240°$ and both sin and cos have a minus sign.

The "Bending" Stiffness Factor A

For members of constant symmetrical section where I is the moment of inertia about an axis parallel to the plane of the members, E the modulus of elasticity, and L the length of the member:

$A = 3EI/L$ when the other end of the member is pinned.
$A = 24EI/7L$ when the other end is half-fixed.
$A = 4EI/L$ when the other end is fully fixed.

These formulas can be used for unsymmetrical sections provided that the principal axes of the section (axes about which there is a maximum and a minimum moment of inertia) are normal and parallel to the plane of the members.

If the member is not of constant section along the length, the amount of moment necessary to produce a slope of one radian at the end of the member can be found by the standard graphical methods.

The "Torsion" Stiffness Factor B

If the member is of constant section and G is the shear modulus of elasticity and L the length of the member: $B = GJ/L$, where J is the torsion constant, a factor corresponding to the moment of inertia in the theory of bending.

For Circular Section, $J = I_p$, the polar moment of inertia.

For Rectangular Section,

$$J = \frac{1}{3}bc^3\left[1 - 0.630\,\frac{c}{b} + 0.052\left(\frac{c}{b}\right)^5\right]$$

where b is the length of the long side.

For thin-walled Non-Circular Section, $J = \dfrac{4A^2}{\int \frac{ds}{t}}$

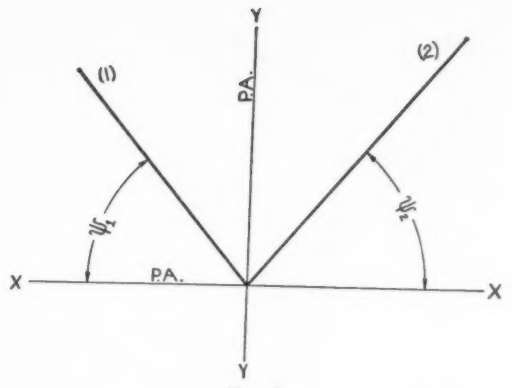

FIG. 5.

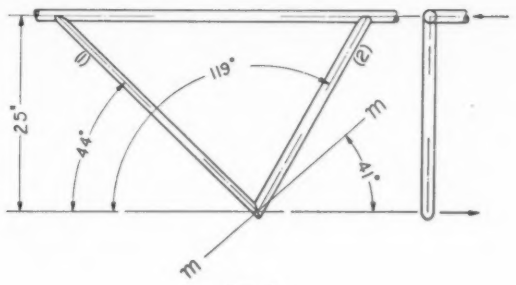

FIG. 6.

where A is the area enclosed by the median line, ds is the differential element of the perimeter, and t is the wall thickness of ds.

Proper account must be taken of the amount of fixity at the end of the member. For a member of a steel tubular fuselage B might equal $.9GJ/L$.

METHOD OF OBTAINING BENDING AND TORSION IN MEMBERS

Once the principal axis is established the bending and torsion in the members can be obtained by several methods of which the following is believed to be the most convenient:

The moment to twist the joint 1 radian about the principal axis x–x, (Fig. 5)

$$= A_1 \sin^2 \psi_1 + B_1 \cos^2 \psi_1 + A_2 \sin^2 \psi_2 + B_2 \cos^2 \psi_2 \quad (2)$$

where ψ is the angle between the principal axis and the member (as shown in Fig. 5) and A and B have the same values as in Eq. (1). The formula can be extended for more members.

The "A" terms make up the amount that produces bending and the "B" terms the amount that produces torsion. Adding the terms and dividing each by the total gives the percentage of the applied moment that is resisted by each term.

Dividing each "A" percentage by sin ψ and each "B" percentage by cos ψ and multiplying by the applied moment results in the bending and torsion in the members due to the applied moment.

The bending and torsion for moment about the other principal axis is obtained in the same manner except that ψ is now the angle between the member and this other principal axis.

ROTATION OF JOINT IN RADIANS

The rotation of the joint in radians about a principal axis $= M_b \sin \psi/A$ or $M_t \cos \psi/B$ where M_b and M_t are the bending and torsion in any one member due to the component of applied moment about that principal axis. Note that M_b and M_t might not be the total bending and torsion in a member as is the case when moment is applied about the other principal axis at the same time. Only the components are used here.

MORE THAN TWO MEMBERS

Generally when there are many members the joint tends to have equal stiffness about any axis and the use of the principal axis is usually an unnecessary refinement. When the members are in the same plane the formulas can easily be extended for any number of members.

An exact solution of members in different planes though, would be very laborious and it is believed that the easiest solution is to use judgment and assume the axis about which the joint rotates. After the bending and torsion have been obtained, summation of moments normal and parallel to the plane of the applied moment can be used as a check. By several trials the axis of rotation can be established if accuracy is desired.

These formulas were derived mainly for use in the design of welded tubular structures, but it is obvious that at least the principles of this paper if not the formulas are applicable to monocoque construction, particularly to the eccentric frames and fittings that often occur.

ILLUSTRATIVE EXAMPLE

Fig. 6 shows two intersecting steel tubular members. The intersection of the members is supported but free to rotate. Let the upper ends of the members have half-fixity in bending and 90 per cent fixity in torsion. A moment is applied to the joint in the plane m–m. Plane m–m, of course, is normal to the plane of the members.

Mbr. (1): $1^1/_8 \times .049$ C.M. steel tube, $I = .0240$ in.^{4}, $L = 35.99$ in.

Mbr. (2): $1^1/_2 \times .065$ C.M. steel tube, $I = .0756$ in.^{4}, $L = 28.58$ in.

$A_1 = 24EI/7L = 24 \times 29{,}000{,}000 \times .0240/7 \times 35.99 = 66{,}300$ in. lbs.

$B_1 = .9GI\rho/L = .9 \times 11{,}500{,}000 \times .0480/35.99 = 13{,}800$ in. lbs.

$A_2 = 24 \times 29{,}000{,}000 \times .0756/7 \times 28.58 = 263{,}000$ in. lbs.

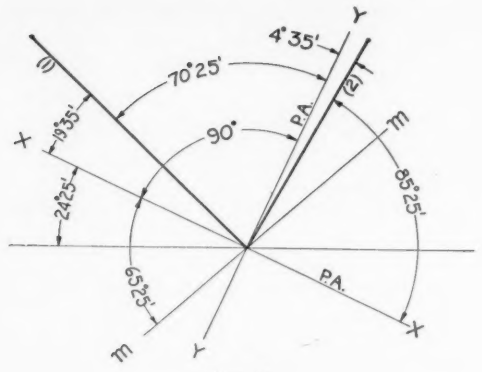

FIG. 7.

$B_2 = .9 \times 11{,}500{,}000 \times .1512/28.58 = 54{,}800$ in. lbs.

$(A_1 - B_1) = 66{,}300 - 13{,}800 = 52{,}500$

$(A_2 - B_2) = 263{,}000 - 54{,}800 = 208{,}200$

Substituting in Eq. (1):

$52{,}500 (\sin 88° \cos 2\beta - \cos 88° \sin 2\beta) +$
$208{,}200 (\sin 238° \cos 2\beta - \cos 238° \sin 2\beta) = 0$

$\cos 2\beta = .65821 \quad 2\beta = 48°50' \quad \beta = 24°25'$

Let the applied moment = 10,000 in. lbs.

Component about the P.A. x–x = M sin 65°25′ = 9094 in. lbs. (Fig. 7)

Component about the P.A. y–y = M cos 65°25′ = 4160 in. lbs.

Applying Eq. (2) about axis x–x, (Fig. 7)

$A_1 \sin^2 19°35' = 66{,}300 \times .33518^2 = 7448$

$B_1 \cos^2 19°35' = 13{,}800 \times .94216^2 = 12{,}250$

$A_2 \sin^2 85°25' = 263{,}000 \times .99680^2 = 261{,}319$

$B_2 \cos^2 85°25' = 54{,}800 \times .07991^2 = 350$

$7448 + 12{,}250 + 261{,}319 + 350 = 281{,}367$

$M_1 = 9094 \times 7448/281{,}367 \times .33518 = 719$ in. lbs.

$T_1 = 9094 \times 12{,}250/281{,}367 \times .94216 = 421$ in. lbs.

$M_2 = 9094 \times 261{,}319/281{,}367 \times .99680 = 8474$ in. lbs.

$T_2 = 9094 \times 350/281{,}367 \times .07991 = 137$ in. lbs.

Applying Eq. (2) about axis y–y, (Fig. 7)

$A_1 = \sin^2 70°25' = 66{,}300 \times .94216^2 = 58{,}852$

$B_1 \cos^2 70°25' = 13{,}800 \times .33518^2 = 1550$

$A_2 \sin^2 4°35' = 263{,}000 \times .07991^2 = 1679$

$B_2 \cos^2 4°35' = 54{,}800 \times .99680^2 = 54{,}450$

$58{,}852 + 1550 + 1679 + 54{,}450 = 116{,}351$

$M_1 = 4160 \times 58{,}852/116{,}531 \times .94216 = 2230$ in. lbs.

$T_1 = 4160 \times 1550/116{,}531 \times .33518 = 165$ in. lbs.

$M_2 = 4160 \times 1679/116{,}531 \times .07991 = 750$ in. lbs.

$T_2 = 4160 \times 54450/116{,}531 \times .99680 = 1950$ in. lbs.

Total $M_1 = 2230 - 719 = 1511$ in. lbs.

Total $T_1 = 421 + 165 = 586$ in. lbs.

Total $M_2 = 8474 + 750 = 9224$ in. lbs.

Total $T_2 = 1950 - 137 = 1813$ in. lbs.

As a check take moments about m–m:

$1511 \sin 85° - 586 \cos 85° - 9224 \sin 20° + 1813 \cos 20° = 1511 \times .9962 - 586 \times .0872 - 9224 \times .3420 + 1813 \times .9397 = 0$

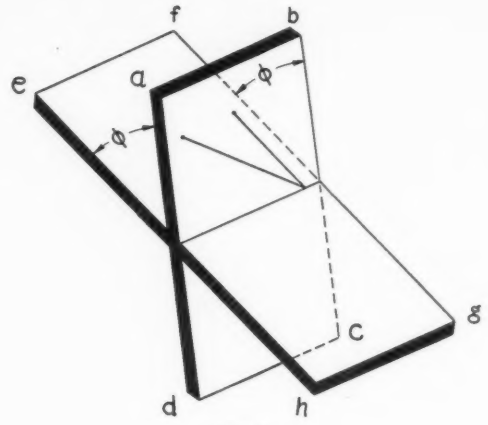

FIG. 8.

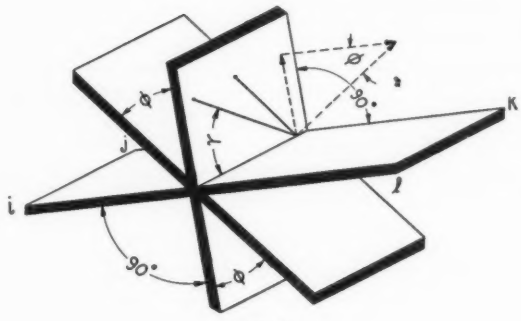

FIG. 9.

Moments in plane of m–m give:

$1511 \cos 85° + 586 \sin 85° + 9224 \cos 20° + 1813 \sin 20° = 1511 \times .0872 + 586 \times .9962 + 9224 \times .9397 + 1813 \times .3420 = 10{,}000$ in. lbs.

Appendix A

Derivation of Formula for Principal Axis

Let A and B equal the moment in in. lbs. necessary to produce a slope and twist, respectively, of one radian at the end of a member.

If the joint is twisted one radian about axis x–x (in Fig. 4) the bending moment in a member = $A \sin (\alpha - \beta)$ and the torsional moment = $B \cos (\alpha - \beta)$.

Moment required about axis x–x for one member

$$= A \sin^2 (\alpha - \beta) + B \cos^2 (\alpha - \beta) \qquad (3)$$

By the definition of the principal axis the components of the moments in the members about axis y–y must equal zero.

Moment about axis y–y for one member

$$= A \sin (\alpha - \beta) \cos (\alpha - \beta) - B \cos (\alpha - \beta) \sin (\alpha - \beta)$$

Then:

$$\Sigma(A - B)[\sin (\alpha - \beta) \cos (\alpha - \beta)] = 0$$

or $$\Sigma(A - B)(\sin 2\alpha \cos 2\beta - \cos 2\alpha \sin 2\beta) = 0 \qquad (4)$$

This gives an equation from which β can be determined. Since $\sin 2\beta = \sin (2\beta + \pi)$, $\beta + \pi/2$ is also a solution.

If Eq. (3) is differentiated with respect to β and equated to zero, Eq. (4) is again obtained which shows that the principal axes are also the axes about which a maximum and minimum amount of rotation occurs.

Appendix B

Resolution of Moments

In order to understand fully the procedure given in this appendix the reader must be familiar with vectorial representation of couples. A couple can be represented by a vector perpendicular to the plane in which its component forces act. The direction of this vector may be determined by the right hand rule, *i.e.*, if the bent fingers of the right hand indicate the direction of rotation that the couple tends to produce, the thumb indicates the direction of the vector. If the lengths of the vectors representing couples are proportional to their respective moments, the couples can be added, subtracted, resolved, and composed graphically in the same manner as forces. The proof of this proposition is given in any good text on mechanics.

Fig. 8 shows the intersection of the plane of the members and the plane of the applied moment. Plane *a b c d* is the plane of the members and *e f g h* that of the applied moment. The intersection of the planes and the true angle between them can be found by means of the standard methods of Descriptive Geometry.

Fig. 9 is the same as Fig. 8 except that plane *i j k l* has been added. This plane is normal or perpendicular to the plane *a b c d* of the members, and passes through the intersection. The vectors shown are perpendiculars to each of the three planes.

It becomes apparent that the component of moment in the plane of the members equals $M \cos \phi$ and the component of moment in the plane normal to the plane of the members equal $M \sin \phi$ where M is the applied moment.

Angle γ, that the intersection of the planes makes with one of the members, is the true angle that the plane normal to the plane of the members makes with that member. In Fig. 6 this would be the angle that *m–m* makes with one of the members.

Personnel Opportunities

The Personnel Bureau serves organizations seeking to employ aeronautical specialists as well as individual members. The Bureau has been the means of arranging several very successful connections for members.

Any member or organization may have requirements listed without charge.

Available

Engineer, 30, at present lecturing on aeronautics abroad, American citizen, seeks connection with airline or manufacturing concern in the United States. Write Box 64, Institute of the Aeronautical Sciences.

Graduate Engineer, B.S.; M.S.; A.E. One year experience as stress analyst. Two years' experience in tunnel testing. Desires position as stress engineer, salary optional. Write Box 65, Institute of the Aeronautical Sciences.

Aeronautical engineer, widely known throughout the industry, desires position as instructor or sales engineer for a high grade accessory manufacturer either here or abroad. Twenty years varied aeronautical experience covering aerodynamical research and design, materials research, and administration. Write Box 66, Institute of the Aeronautical Sciences.

Cooling of a Radial Engine in Flight

OSCAR W. SCHEY and BENJAMIN PINKEL, *National Advisory Committee for Aeronautics*

Presented at the Engines and Fuels Session, Fifth Annual Meeting, I. Ae. S.
January 28, 1937

Introduction

A STUDY of the heat-transfer processes of air-cooled engine cylinders has been made at the laboratories of the National Advisory Committee for Aeronautics on single-cylinder blower-cooled test engines. Because of the difference in airflow conditions between a blower-cooled engine and a cowled engine in flight, it was considered advisable to make flight tests to correlate with the laboratory tests. The present paper gives the results of flight tests to determine the effect of indicated horsepower and mass flow of cooling air on cylinder temperatures and shows the correlation between these results and the results of the laboratory tests.

The main difficulty attending the study of engine cooling in flight is the independent control and measurement of the many engine and cooling variables so that their separate effects may be studied. In the present tests an attempt was made to obtain complete control of the test conditions. A novel feature of the tests was the method used for independently varying the velocity of the cooling air and the cylinder horsepower of the engine.

Analysis

It has been shown[1] that from cooling considerations, an air-cooled engine may be considered in terms of the equivalent heat exchanger shown in Fig. 1. The quantity W_T, the weight flow of gases through the center of the exchanger, is equal to the weight of charge flowing through the engine per minute adjusted to include residuals; the quantities W_h and W_b, the weight flows of air around the tube, are equal, respectively, to the weight of cooling air flowing per minute around the head and barrel of the engine. The quantity T_a is the inlet temperature of the cooling air; T_h and T_b, the average temperatures of the cylinder head and barrel; and $T_g(H)$ and $T_g(B)$, the average effective temperature of the gas as it flows over the head and barrel, respectively. Tests of a number of service cylinders, including the Pratt & Whitney 1535, showed that the values of T_g for the head and the barrel were in the neighborhood of 1150°F. and 600°F., respectively. The values of T_g were found to vary with air-fuel ratio, spark timing, and carburetor-air temperature for a given engine.

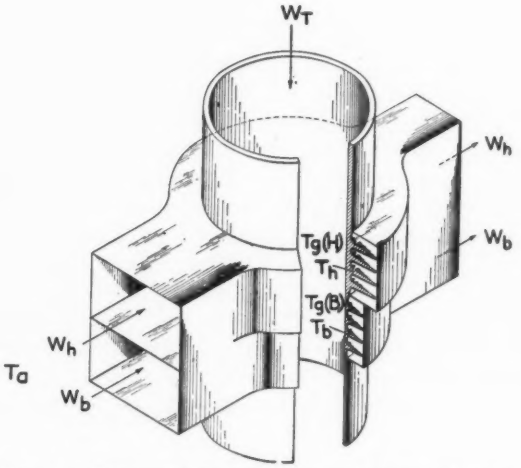

FIG. 1. Diagrammatic view of heat exchanger equivalent of air-cooled cylinder.

From a consideration of the heat transfer in this heat exchanger some idea can be obtained of the effect of indicated horsepower and of mass flow of cooling air on cylinder temperature.[2] The rate of heat transfer between a body and a gas is equal to the product of the area of the body, the heat-transfer coefficient, and the temperature difference between the body and the gas. Thus, the rate of heat transfer from the engine gases to the cylinder head is given by

$$H = a_1 Q_g (T_g - T_h) \tag{1}$$

and from the cylinder head to the cooling air by

$$H = a_0 U (T_h - T_a) \tag{2}$$

where a_1 is the internal area, a_0 the external area of the head, Q_g the surface heat-transfer coefficient on the inside of the head, and U the overall heat-transfer coefficient for the outside base area of the head. For equilibrium the heat transferred to the cylinder head is equal to that removed by the cooling air; the following equation may be obtained for the average cylinder-head temperature:

[1] Benjamin Pinkel, *Heat-Transfer Processes in Air-Cooled Engine Cylinders*, to be published.

[2] For detailed analyses see reference given as footnote 1.

$$T_h - T_a = \frac{T_g - T_a}{\frac{a_0 U}{a_1 Q_g} + 1} \tag{3}$$

A similar set of equations may be written for the barrel.

The heat-transfer coefficients are porportional to some power of the weight velocity of the air and gases flowing. Thus U and Q_g can be written as proportional to W_h^m and W_T^n, respectively. With no variation in the weight of residuals and with air-fuel ratios richer than the chemically correct mixture, the variation in indicated horsepower may be used as a measure of the variation in W_T, and Q_g may be written as proportional to I^{n_1}. The weight flow of cooling air W_h is proportional to the mass flow. In the present paper the mass flow is given in terms of the ratio of the actual mass flow to a constant density $V\rho/\rho_0$, and has the same units as velocity (V is the cooling air speed, ρ the actual density, and ρ_0 a density corresponding to 70°F. at 29.92 in. Hg).

Eq. (3) may then be written

$$T_h - T_a = \frac{T_g - T_a}{K \frac{(V\rho/\rho_0)^m}{I^{n_1}} + 1} \tag{4}$$

where K is a constant for a given engine and cooling set-up. The values for n_1 and m obtained for the head in tests of a Pratt & Whitney 1535 cylinder on a single-cylinder test stand are 0.68 and 0.70, respectively. For the barrel the value of m is 0.62, but inconsistent results were obtained in these tests for the value of n_1. However, other tests of a Pratt & Whitney 1535 cylinder and tests of a Pratt & Whitney 1340-H indicate that the value of n_1 for the barrel is the same as for the head.

It is customary to express the temperature difference between the cylinder and air as varying with the indicated horsepower raised to an exponent $\bar{n}_1$. It can be seen from Eq. (4) that $\bar{n}_1$ is not constant but is related to n_1 by

$$\bar{n}_1 = \alpha\, n_1$$

where

$$\alpha = \frac{T_g - T_h}{T_g - T_a} \tag{5}$$

Similarly $\bar{m} = \alpha\, m$ will be the exponent for the variation of the temperature difference with mass flow. It is evident that the value of the exponents $\bar{n}_1$ and $\bar{m}$ will depend on the temperature range covered. Fig. 2 shows α plotted for the head and barrel. Curves are also shown in Fig. 2 to illustrate the range over which $\bar{n}_1$ may be expected to vary for a value of n_1 of 0.68. The range of variation of $\bar{m}$ would be very similar as the value of m is close to that of n_1.

By rewriting Eq. (4) as follows

$$\frac{T_g - T_h}{T_h - T_a} = K \frac{(\rho V/\rho_0)^m}{I^{n_1}} \tag{6}$$

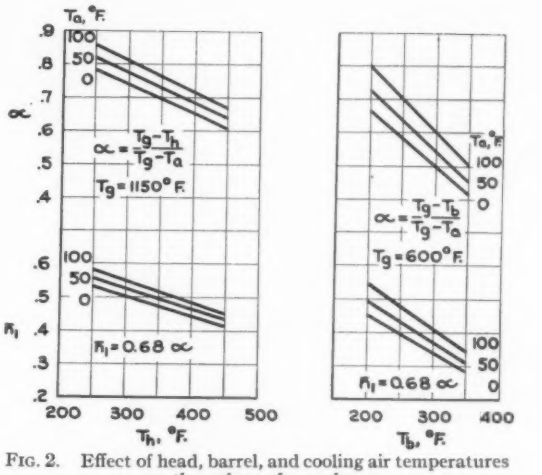

FIG. 2. Effect of head, barrel, and cooling air temperatures on the values of α and n_1.

a temperature ratio is obtained which varies with a constant power of the indicated horsepower and mass flow.

Eq. (6) will be used to obtain the exponents n_1 and m from the flight tests for comparison with the values obtained in the laboratory tests.

TEST EQUIPMENT

The flight tests were made on a Grumman Scout (XSF-2) airplane. The airplane was equipped with a Pratt & Whitney 1535–72, 14-cylinder, 2-row radial engine having a compression ratio of 6.7:1, an impeller-gear ratio of 12:1, and a rated horsepower of 650 at an altitude of 7500 ft. A continuously variable Smith propeller from which the stops have been removed was provided for controlling the engine speed.

In order to obtain independent control of the airplane speed and the cylinder power, the spark plugs of the rear-row cylinders were connected to knife switches so that they could be individually short-circuited in flight. All temperature measurements were made on cylinders 4 and 12 of the front row. By this means, the power delivered to the propeller and the airplane speed could be varied without changing the power conditions of the cylinders on which the thermocouples were located.

The thermocouples were placed on cylinders 4 and 12 because these cylinders have nearly horizontal axes and are least affected by distortion of the flow around the cowling at large angles of attack. The thermocouple locations on cylinder 4 are shown in Fig. 3. Seven thermocouples were located on the head, four on the barrel, and one on the flange. The thermocouple locations were chosen from 34 used in the single-cylinder tests and the original numbers were retained. Thermocouples were located on cylinder 12 at positions 6, 12, 14, 15, 19, and 29 for the purpose of checking the results obtained on cylinder 4. A pitot tube was placed on the head of cylinder 4 in the space between

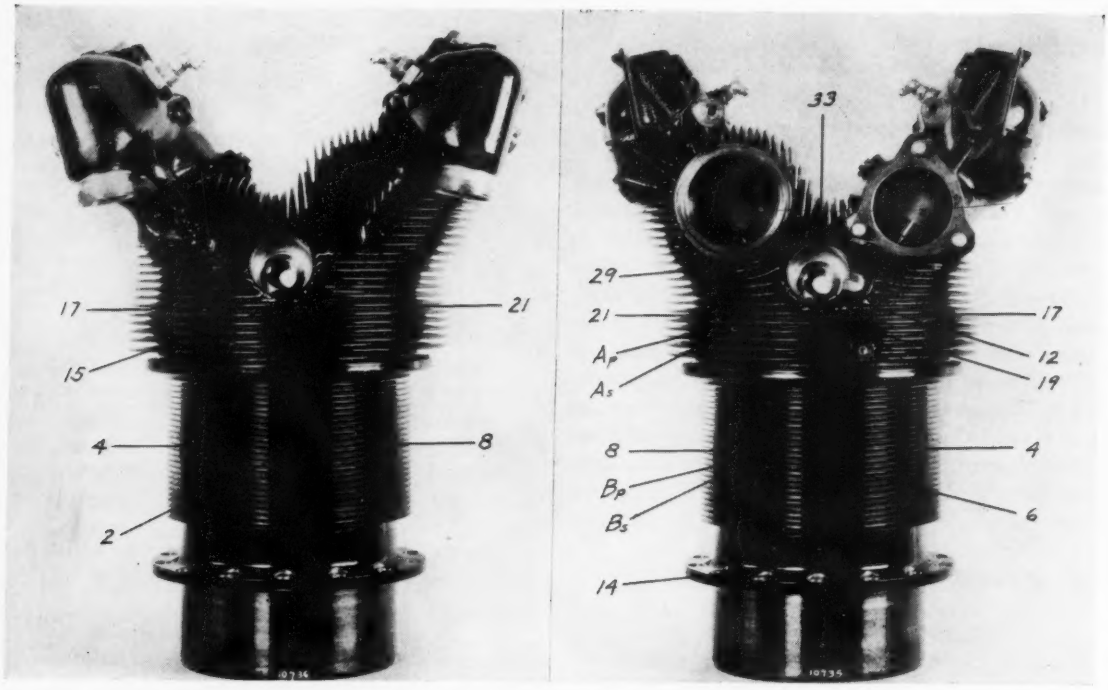

FIG. 3. Front and rear view of P. & W. 1535 cylinder showing locations of thermocouples, pitot tubes, and static tubes.

two fins 135° from the front and a static tube was located in the adjacent space at the same angular position, thus providing a means for measuring an air speed between fins on the head. The locations of these tubes are designated A_p and A_s, respectively, in Fig. 3. Pitot and static tubes were also located in a similar position on the barrel and their locations are designated by B_p and B_s, respectively, in the figure. Static tubes were located in front of and behind the cylinder for obtaining the pressure drop. The pitot and static tubes were connected to a recording manometer.

An N.A.C.A. fuel flowmeter was provided for measuring the rate of fuel consumption. An air-fuel-ratio meter would have been a valuable addition to the equipment but was not available at the time. An alcohol thermometer located on a strut of the airplane measured the atmospheric temperature. A resistance thermometer measured the carburetor-air temperature. The pressure altitude was obtained from the calibrated altimeter, the manifold pressure from a calibrated pressure gauge, and the airplane speed from a calibrated air-speed meter. The engine power was obtained from calibration curves and the values given in the paper are on the basis of all cylinders firing.

RESULTS AND DISCUSSION

The effect of engine power on cylinder temperature was investigated at an altitude of 3200 ft. The airplane was flown at a low velocity ($\rho V/\rho_0 = 134$ m.p.h.) with the engine throttled to a low manifold pressure and all cylinders firing. As cylinders were shorted out,

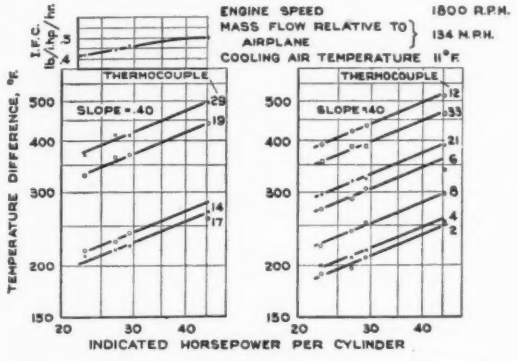

FIG. 4. Effect of i.hp. on temperature difference between cylinder and cooling air.

the airplane speed was maintained constant by increasing the manifold pressure. In this manner the power of cylinder 4 was varied without changing the mass flow of cooling air. The mixture control was set at the full-rich position, as changes in air-fuel ratio in the rich range have the least effect on cylinder temperatures, and no adjustment was made during the test. The engine speed was held constant at 1850 r.p.m.

The difference between the cylinder temperature and the cooling-air temperature is shown plotted against indicated horsepower on logarithmic coordinates in Fig. 4. The slope of the curves is 0.40. From the indicated fuel consumption shown in Fig. 4 it is evident that a variation in air-fuel ratio occurred during the test.

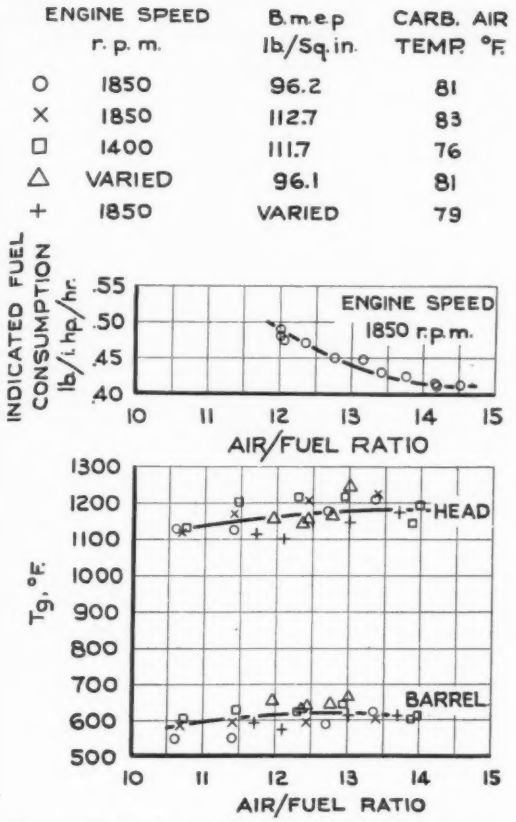

FIG. 5. Effect of air-fuel ratio on indicated fuel consumption and effective gas temperature T_g of the 1535 cylinder.

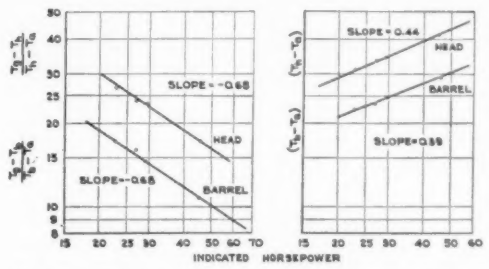

FIG. 6. Effect of indicated horsepower on average temperature difference between head and cooling air and barrel and cooling air and on factors $(T_g - T_h)/(T_h - T_a)$ and $(T_g - T_b)/(T_b - T_a)$.

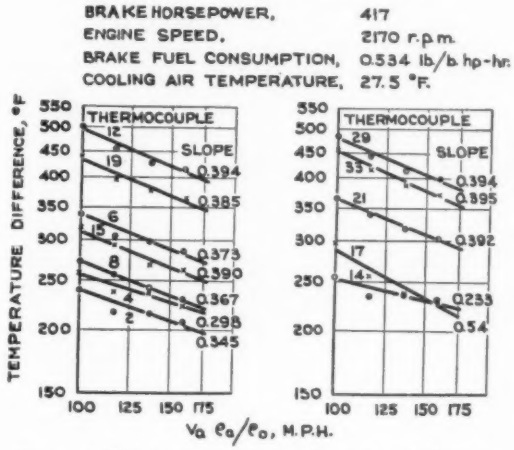

FIG. 7. Effect of mass flow relative to the airplane on temperature difference between cylinder wall and cooling air.

In order to obtain the value for the exponent n_1 for the head and barrel, it is necessary to determine the values of T_g, T_h, and T_b (Eq. (6)). The values of T_g for the head and barrel corresponding to the indicated fuel consumption in Fig. 4 were read from the curves in Fig. 5. These curves, showing the variation of indicated fuel consumption and T_g with air-fuel ratio, were obtained from the laboratory tests on a Pratt & Whitney 1535 cylinder. In all the flight tests the manifold-charge temperatures were practically constant during each flight and were sufficiently close to the value at which the tests to determine T_g were made so that no correction for manifold temperature was necessary. The values of T_h and T_b were obtained by averaging the readings of the thermocouples on the head and barrel, respectively.

The values of the temperature ratios $(T_g - T_h)/(T_h - T_a)$ and $(T_g - T_b)/(T_b - T_a)$, calculated from the foregoing values of T_g, T_h, and T_b, are shown plotted in Fig. 6 on logarithmic coordinates against the indicated horsepower. As Eq. (6) shows, the slopes of the curves of 0.68 for both the head and barrel are the values for the exponent n_1. This value agrees exactly with the value obtained in the laboratory tests for the head.

The average temperature difference, corrected to a constant air-fuel ratio, is also shown plotted in Fig. 6. The correction was made by multiplying the actual temperature difference by $(1150 - T_a)/(T_g - T_a)$ for the head and by $(620 - T_a)/(T_g - T_a)$ for the barrel (see Eq. (4)). The slopes of these curves give values for $\overline{n_1}$ of 0.44 for the head and of 0.39 for the barrel. Reference to Fig. 2 gives a value of 0.47 for the head and of 0.40 for the barrel, corresponding to the average T_h and T_b for the range covered and a cooling-air temperature of 11°F.

In the tests to determine the effect of mass flow, the airplane velocity was varied by shorting the spark plugs of cylinders in the rear row. The power of the cylinders tested was held constant by maintaining a constant manifold pressure and engine speed. The mixture control was set at the full-rich position and no further adjustment was made and, as was expected, the fuel-air ratio remained practically constant. Three test flights were made at the test conditions shown in Table 1. The last two were made on the same day.

Fig. 7 shows the temperature difference between the cylinder and the cooling air for flight 1 plotted against the mass flow of air relative to the airplane. Average values of 0.39 and 0.35 were obtained for the exponent $\overline{m}$ for the head and barrel, respectively.

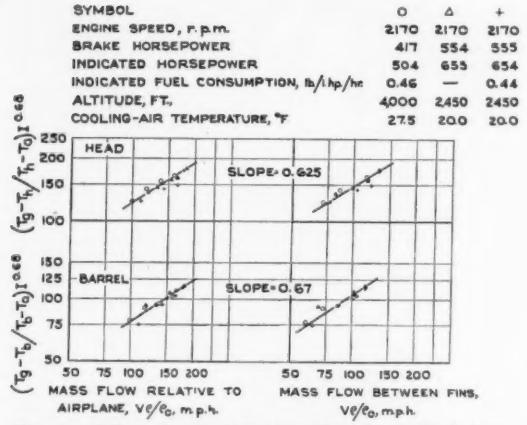

FIG. 8. Effect of mass flow of cooling air on the factors $[(T_g - T_h)/(T_h - T_a)]I^{n_1}$ and $[(T_g - T_b)/(T_b - T_a)]I^{n_1}$

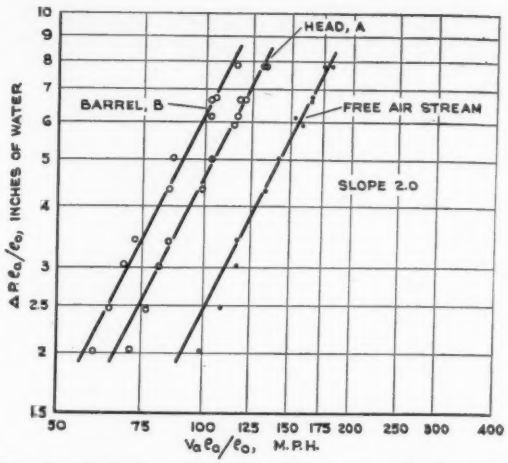

FIG. 9. Variation of pressure drop across cylinder with mass flow between fins and the mass flow relative to airplane.

TABLE 1

Test Flight	Altitude (Feet)	B.hp.	Engine Speed (R.p.m.)	T_a (°F.)	Indicated Fuel Consumption (Lb./I.hp./Hr.)
1	4000	417	2170	27.5	0.46
2	2450	554	2170	20.0	
3	2450	555	2170	20.0	.44

Eq. (6) may be written

$$\left(\frac{T_g - T_h}{T_h - T_a}\right) I^{n_1} = K\left(\frac{\rho V}{\rho_0}\right)^m \qquad (7)$$

The quantities $(T_g - T_h)/(T_h - T_a)I^{0.68}$ and $(T_g - T_b/T_b - T_a)I^{0.68}$ are shown plotted on logarithmic coordinates in Fig. 8 against the mass flow relative to the airplane and the mass flow between fins. The fact that the points for the three flights fall on a single curve is a further check on the value of n_1. The slopes of these curves give values of 0.63 and 0.70 for m for the head and barrel, respectively, as compared with values of 0.70 and 0.62 obtained in the laboratory tests.

There is a difference in the airflow between a cowled engine in flight and a blower-cooled cylinder. In the former case the front half of the cylinder is cooled partly by the large-scale turbulence in the air under the cowling, some of this air spilling out over the nose of the cowling. The air approaching the cylinder cooled by the blower was smooth and all the air that flowed over the front of the cylinder passed around to the rear. As the exponent m depends on the airflow condition, some difference between the laboratory and flight values is to be expected.

It should also be noted that different temperatures are obtained when the mass flow between fins is varied by changing the exit opening of the cowling than when the flow is varied by changing the airplane speed, for in the former case the change in mass flow around the rear half does not increase the mass flow over the front to the same degree.

Multiplying the values of m by the values of α given in Fig. 2, which correspond to the average T_h, T_b, and T_a for flight 1, values for $\overline{m}$ of 0.41 and 0.37 are obtained for the head and barrel, respectively. These values are to be compared with the values obtained from Fig. 7 for $\overline{m}$ of 0.39 for the head and of 0.35 for the barrel.

In the range covered, the velocity between fins was approximately proportional to the airplane velocity. At very high angles of attack, or for cowlings for which the propeller slipstream has a large effect on the pressure drop across the engine, the linear relation between airplane speed and velocity of air between fins breaks down and it is better to use the latter, or the pressure drop across the cylinder, as a criterion of the mass flow. Fig. 9 shows the mass flow relative to the airplane and the mass flow between the fins on the head and barrel plotted against $\Delta P\rho/\rho_0$, where ΔP is the pressure drop across the cylinder.

An attempt was made to obtain the effect of atmospheric temperature on cylinder temperature by flying at various altitudes while a constant mass flow and engine power were maintained. The results of the tests were inconclusive owing to the small variation of cooling-air temperature for the altitude covered. The effect of cooling-air temperature on cylinder temperature may readily be obtained from Eq. (4) and is given in Fig. 2 by α, which is the variation in cylinder temperature per degree change in cooling temperature, provided mass flow and the engine-power conditions remain constant.

The results of these flight tests show satisfactory correlation with the laboratory tests in fitting into the picture of cooling obtained from a study of the laboratory tests.

Two New Longitudinal Stability Constants

ALEXANDER KLEMIN and J. G. BEERER, JR., *New York University*

(Received May 17, 1937)

AT THE fifth annual meeting of the Institute some notes were presented by the first author under the title, "Design Application of Longitudinal Dynamic Stability." Further study indicated that more emphasis should be placed on two stability coefficients suggested at this meeting, and the title of the paper has been changed accordingly. Its purposes remain the same, however, first, to extend discussion of what really should be the desirable characteristics of the longitudinal motion of an airplane with controls in neutral; second, to bridge the gap between highly theoretical work on dynamic stability, and the practical work of the airplane designer who is content with the simplest routine tests in the wind tunnel, and reliance on Diehl's Stability Coefficient.

Views of Engineer-Pilots on Desirable Longitudinal Motion

As an introduction to the investigation, a questionnaire was sent to a number of well-informed engineers who are pilots, and very helpful replies were received from Holden C. Richardson, D. J. Brimm, Jr., J. M. Gwinn, Jr., and L. C. Miller. The following interpretation of these replies as regards desirable longitudinal motion should, however, be considered as solely the responsibility of the writers:

(1) There should be static stability, since otherwise the ship does not return to original trim.

(2) The static stability must not be so great as to ruin the maneuverability, cause the machine to take charge in gusty air, or give too short a period of oscillation, which unless very heavily damped is apt to be uncomfortable.

(3) The static stability should not be so low as to give a long disagreeable period which leaves the occupants wondering whether the ship is ever going to come back. A long, slow oscillation, like the wallowing effect of an ocean liner, produces more air sickness than short, quick oscillations.

(4) A complete longitudinal oscillation should not, as a rule, be longer than forty seconds, nor shorter than ten seconds.

(5) Heavy damping of the motion is always desirable, be the period short or long.

(6) No airplane, left to itself, should oscillate more than four or five times before the motion becomes imperceptible.

(7) Satisfactory periods of oscillation and times to damp to half amplitude, are a matter of pilot's and passenger's reactions.

(8) The longitudinal motion as related to time, of an airplane should not be too greatly dependent on the speed, loading, or size. All types of aircraft will appear satisfactory to pilot and passenger if the character of the longitudinal motion related to time does not depart too much from the average.

It is in this last paragraph that will be found the keynote to the present investigation.

Symbols Used in Text

l = linear dimension, ft.
w = wing loading, lbs. per sq. ft.
ρ = air density in slugs ft.
l_t = distance from c.g. of airplane to elevator hinge line, ft.
S_t = horizontal tail surface area in sq. ft.
K_B = radius of gyration in pitch, ft.
S_W = wing area in sq. ft.
m = mass of airplane.
U = forward velocity of airplane in ft. per sec.
V_s = stalling velocity of airplane in m.p.h.
$\frac{dC_{Lt}}{d\alpha_t}$ = slope of lift curve of horizontal tail surface in radians.
η = efficiency of horizontal tail surface.
q = $\rho V^2/2$.
c = mean aerodynamic chord in feet.
P = period of oscillation in seconds.
T = time to damp to half amplitude in seconds.
M_q = damping derivative referred to unit mass.
M_θ = static pitching moment derivative referred to unit mass.
M_w = static moment derivative referred to unit mass.

Character of Longitudinal Oscillation as Affected by Changes in Airplane Design

The next step in this investigation of longitudinal stability was a thorough study of the classical equations of motion.[1]

Changes in the longitudinal oscillation were observed following systematic variations in the characteristics of a hypothetical airplane used in these calculations.

[1] Jerome C. Hunsaker, *Stability of Aeroplanes*, Smithsonian Miscellaneous Collections, Vol. 62, June, 1916.

TABLE 1

Characteristics of Airplanes Investigated

	Airplane							
	F-22	A	B	C	D	E	F	G
General	2-Place Open Parasol Monoplane	2-Place Open 1-Bay Biplane	6–8 Place 2-Engine Amphibian Cabin Monoplane	4-Place 2-Engine Cabin Monoplane	10-Place Single-Engine Amphibian Cabin Monoplane	4–5-Place Single-Engine Low-Wing Cabin Monoplane	1-Place Closed Low-Wing Monoplane	36-Place 2-Engine Monoplane Seaplane
Gross weight, lbs.	1440	2650	7200	2700	10,000	3600	5043	170,000
Hp.	90	145	800	300	750	225	1100	10,000
Wing area, sq. ft.	170.0	304.0	375.0	205.0	475.0	248.0	160.0	10,000
Span, ft.	32.8	33.5	49.0	36.0	56.5	39.5	31.0	250.0
MAC, ft.	5.50	5.00	7.85	5.98	9.00	6.66	5.25	43.65
Overall length, ft.	22.0	25.0	38.0	21.5	45.0	30.2	23.0	130.0
Overall height, ft.	7.8	10.5	13.0	7.0	15.0	8.7	8.7	30.0
C.G. to elevator hinge, ft.	13.15	14.60	21.80	15.00	28.50	21.90	13.50	82.20
Horizontal tail area, sq. ft.	26.2	37.4	87.0	24.2	79.0	39.6	26.2	1775.0
Wing loading, lbs./sq. ft.	8.48	8.72	19.20	13.16	21.00	14.50	31.4	17.0
Stalling velocity, m.p.h.	54.5	59.6	90.6	70.6	86.0	73.0	117.5	73.0
C.G. location								
% along MAC	28.5	26.8	25.0	25.0	29.5	26.5	23.0	27.5
% below MAC	57.5	33.3	22.0	0	12.0	−5.0	−15.0	14.0
Moment of inertia in pitch (slug ft.^{2})	879	2170	12,960	1546	25,200	3970	3400	2,820,000
Radius of gyration in pitch (ft.)	4.44	5.14	7.60	4.29	9.00	5.95	4.66	23.1

The following conclusions have been drawn from this study:

(1) *Effect of change in linear dimensions only.* Increase in linear dimensions and decrease in static stability will substantially increase the period of the long oscillation, but will not affect the damping time appreciably.

(2) *Effect of changes in loading only.* Increase in loading will cause increased damping times while the period will be increased only indirectly by the decrease in damping.

(3) *Effect of density only.* A decrease in density in a given ratio is equivalent to an increase in loading in the inverse ratio.

(4) *Effect of change in radius of gyration only.* Increase in radius of gyration will increase the damping time more than the period, but on the whole the effect is of small magnitude.

(5) *Effect of change in the static pitching moment derivate, M_θ only.* When M_θ alone is varied the period is affected powerfully, decreasing with increase in M_θ.

(6) *Effect of change in damping derivative, M_q, only.* When M_q is increased, the time to damp is appreciably reduced but the period is lengthened.

(7) *Effect of change of forward velocity.* The period of oscillation decreases sharply with decrease in speed, and the damping time increases moderately as the speed decreases.

METHOD OF STUDY OF SIMULTANEOUS CHANGES IN LOADING, LINEAR DIMENSION, AND DENSITY

Glauert, in a pioneer paper,[2] showed how the effects of simultaneous changes in loading, linear dimension, and density might be studied by the use of new units of length and time, and non-dimensional derivatives. In practical design it would seem preferable to start with dimensional derivatives obtained from practical wind-tunnel experimentation.

[2] H. Glauert, *A Non-Dimensional Form of the Stability Equations of an Aeroplane*, British R. & M. No. 1093.

TABLE 2

Longitudinal Stability Characteristics of Ships Investigated*

	Airplane							
	F-22	A	B	C	D	E	F	G
Velocity in glide, m.p.h.	112.0	136.4	202.5	168.0	160.0	177.0	260.0	144.0
V/V_s	2.055	2.290	2.240	2.380	1.860	2.420	2.213	1.970
Period, seconds	30.8	36.5	55.8	44.0	44.5	44.1	59.5	68.3
Time to damp to half amplitude, seconds	10.5	14.1	26.2	31.4	43.4	33.3	49.5	54.4
T/p	0.341	0.386	0.470	0.715	0.975	0.755	0.832	0.797
M_w	−2.130	−2.210	−2.095	−2.640	−1.910	−2.140	−0.805	−6.250
M_q	−78.9	−89.0	−147.0	−130.0	−205.5	−98.0	−35.4	−2720.0
$dC_m/d\alpha$ per degree	−0.0100	−0.0096	−0.0086	−0.0118	−0.0095	−0.00900	−0.00630	−0.00579
Diehl's K_D	−0.00118	−0.00110	−0.00045	−0.00090	−0.00045	−0.00062	−0.00020	−0.00034
K_z	−0.1290	−0.1070	−0.0650	−0.1580	−0.0605	−0.0870	−0.0773	−0.0144
K_{q1}	−12.20	−10.40	−11.60	−26.80	−12.20	−11.00	−9.50	−22.50
K_{q2}	1.560	1.085	0.825	2.260	1.085	0.890	0.521	2.180

* These calculations have been made using an air density of 0.00217, corresponding to 3000 ft. altitude.

The authors have found it most convenient to study the effects of these simultaneous changes by the introduction of a single parameter of the form:

$$\Gamma = \frac{w_r}{\rho_r l_r}$$

where

w_r = loading ratio
ρ_r = density ratio
l_r = linear dimension ratio

With the introduction of this parameter, the new unit of time, t', is connected to the usual unit, t, in seconds, by the relation:

$$t' = t(\rho_r/w_r)^{1/2}$$

The determinantal equation of motion now assumes this character:

$$\begin{vmatrix} D - X_u & -X_w & g\cos\theta_0 \\ -Z_u & D - Z_w & -UD + g\sin\theta_0 \\ 0 & -M_w\Gamma & K_B^2D^2 - M_qD \end{vmatrix} = 0$$

where the various symbols have their usual meaning.[1]

Thus the original determinantal equation is unchanged except for the presence of the parameter Γ in the one form.

With the aid of this parameter, it is possible to take an airplane of known stability characteristics and to observe the changes which occur in its stability following simultaneous variations in its size, wing loading, and the density of the air through which it will fly.

Dynamic Stability of Contemporary Airplanes

The longitudinal power-off dynamic stability of several ships has been calculated from wind-tunnel tests conducted at New York University.

The general characteristics of these airplanes are given in Table 1 and the results of the stability calculations are given in Table 2, and plotted in Figs. 2 to 6. Calculations were made for the entire speed range, but the tabulated values are for V/V_s of approximately 2. Fig. 1 shows the characteristics of the Fairchild F-22.

A Proposed Static Stability Coefficient. The Non-Dimensional Aerodynamic Stability Coefficient

In the early days of applied aerodynamics, it was customary to use a static stability coefficient defined by the equation:

$$\frac{dM_{c.g.}}{d\alpha} = K_A qSc$$

so that:

$$K_A = \frac{dM_{c.g.}}{d\theta} \cdot \frac{1}{qSc} = \frac{dC_{Mc.g}\,qSc}{d\theta\ \ qSc} = \frac{dC_{Mc.g.}}{d\theta}$$

was non-dimensional. The use of this coefficient implied that the designer sought to obtain a restoring moment exactly proportional to the area of the wings, the mean aerodynamic chord, and the loading per square foot.

Again,

$$\frac{\partial M}{\partial\theta} \text{ or } M_\theta \propto \frac{dM_{c.g.}}{md\theta} \propto \frac{K_A qSc}{qS} \propto K_A c$$

so that the designer was seeking to make M_θ propor-

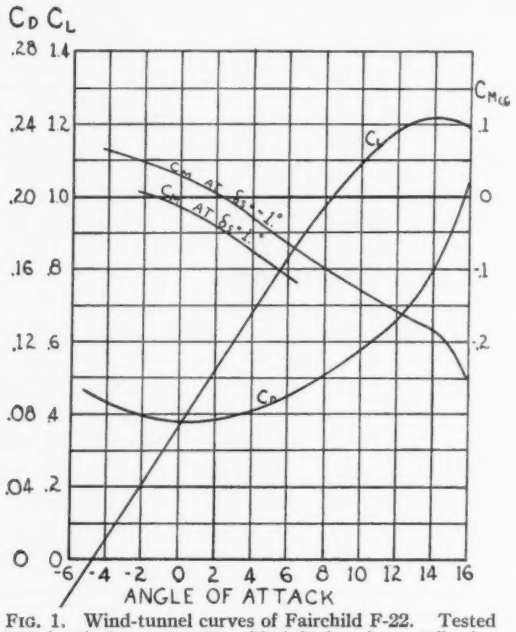

FIG. 1. Wind-tunnel curves of Fairchild F-22. Tested in 9 ft. wind tunnel at New York University. Effective R.N. = 417,000.

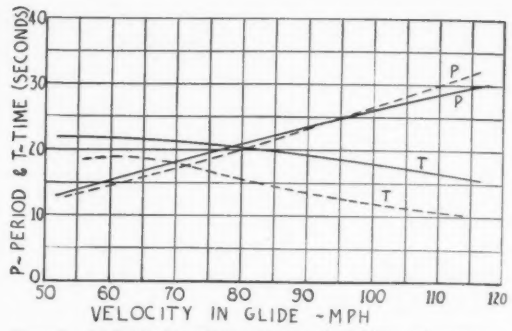

FIG. 2. Fairchild F-22 longitudinal stability characteristics. Solid lines are from full-flight tests at the N.A.C.A.[6] Dotted lines are calculated from wind-tunnel tests at New York University.

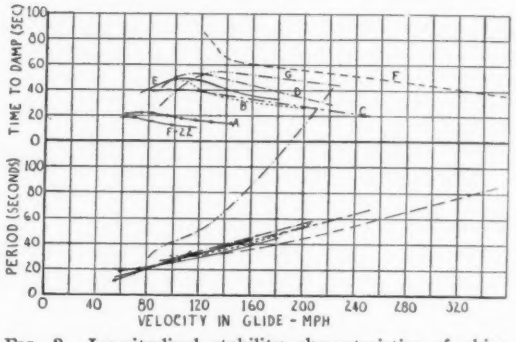

FIG. 3. Longitudinal stability characteristics of ships investigated, calculated from wind-tunnel tests at New York University.

tional merely to the mean aerodynamic chord of the airplane.

If the pitching equation is written with only the static stability considered:

$$K_B^2 \frac{d^2\theta}{dt^2} = M_\theta \theta$$

the period:

$$P \propto \frac{1}{\sqrt{M\theta/K_B^2}}$$

and if: $M_\theta \propto c$,

$$P \propto \frac{1}{\sqrt{c/K_B^2}} \propto \sqrt{K_B^2/c} \propto l_r^{1/2}$$

Stated still another way, the designer was trying to make the period of oscillation independent of loading or density, and increasing it with the size of the airplane.

The only reference giving a discussion of K_A is that due to the author,[3,4] and without any other reasoned discussion appearing in the literature of the art, the constant K_A was gradually discarded and gave way to Diehl's Constant.

DIEHL'S CONSTANT FOR STATIC STABILITY

Diehl's Constant of static stability K_D is characterized by the equation[5]:

$$\frac{dM_{c.g.}}{d\theta} = K_D q W c$$

so that:

$$K_D = \frac{1}{qWc} \cdot \frac{dM_{c.g.}}{d\alpha} = \frac{1}{qWc} \cdot \frac{dC_{Mc.g.}}{d\alpha} qSc = \frac{1}{w} \frac{dC_{Mc.g.}}{d\alpha}$$

and

$$\frac{dC_{Mc.g.}}{d\alpha} = wK_D$$

In other words, with a constant value of K_D, the designer sought to increase the aerodynamic coefficient of static stability with the loading per square foot of wing area of the airplane.

Again:

$$\frac{\partial M}{\partial \theta} = M_\theta \propto \frac{1}{m} K_D q W c \propto K_D q c$$

so that with a constant value of K_D: $M_\theta \propto wc$, since for the pitching equation with only the static stability considered,

$$P \propto \frac{1}{\sqrt{M_c/K_B^2}} \propto \sqrt{K_B^2/M_\theta} \propto \sqrt{K_B^2/wc} \propto \sqrt{l/w}$$

[3] Alexander Klemin, *Longitudinal Stability for Very Large Airplanes*, Aviation Engineering, December, 1929.

[4] Alexander Klemin, *The Longitudinal Stability Coefficient*, Aviation Engineering, November, 1929.

[5] Walter S. Diehl, *Engineering Aerodynamics*, pages 105 and 185, The Ronald Press Company, New York, 1936.

[6] Hartley A. Soule, *Flight Measurements of the Dynamic Longitudinal Stability of Several Airplanes*, N.A.C.A. Technical Report No. 578.

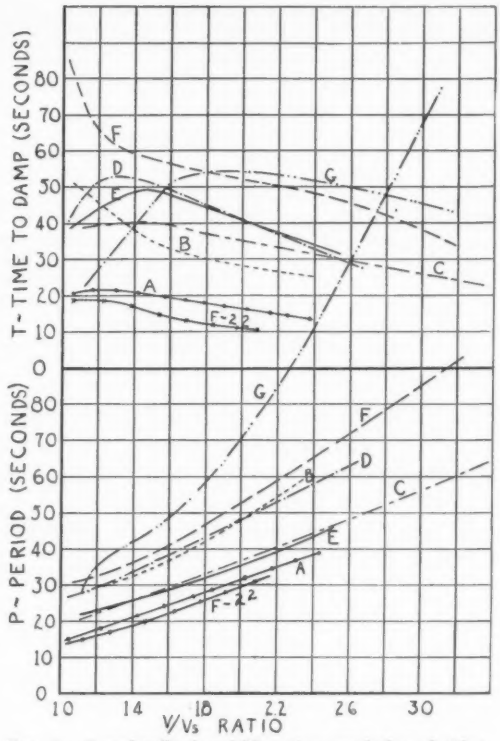

FIG. 4. Longitudinal stability characteristics of ships investigated.

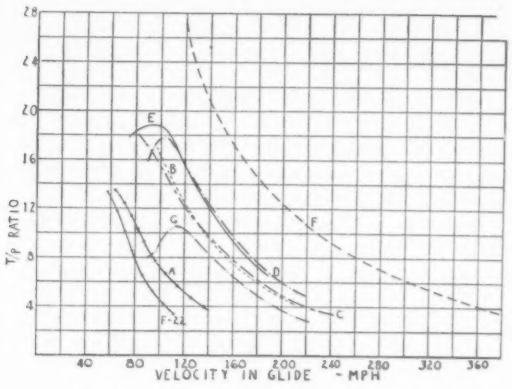

FIG. 5. T/P ratios for ships investigated.

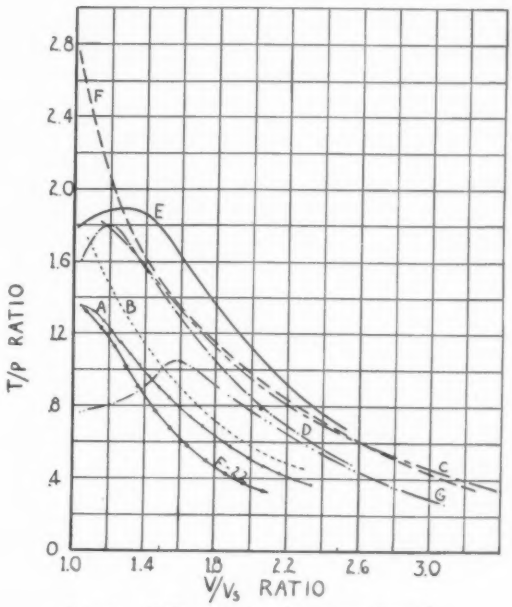

FIG. 6. T/P ratios for ships investigated.

the designer now sought to make the period (1) increase as the square root of the linear dimensions of the airplane, and (2) vary inversely as the square root of the loading.

It is the Diehl Constant which is most frequently used by designers today, and it has given satisfactory results in experienced hands. Diehl's Constant has been satisfactory because when the designer increased the static stability, he was led, indirectly, to increase the tail surface area or length of tail arm or both, and thus to increase the damping.

Nevertheless, Diehl's Constant may be criticized on the following grounds:

(1) Since $\frac{dC_{M_{c.g.}}}{d\alpha} = wK_D$, a heavy wing loading would lead the designer to seek in the wind-tunnel tests a perhaps unnecessarily large static restoring moment.

(2) It only introduces control of the damping moment indirectly.

(3) Its direct physical significance is not evident.

(4) It does not take care of change in density in altitude flying.

(5) For a very large machine, its use would tend to give too long a period.

(6) For a very heavily loaded machine it would tend to give too short or rapid period of oscillation.

It would appear, therefore, desirable to develop a more logical constant for the static stability, and another constant which should give some information on the damping.

A Proposed New Coefficient of Static Stability

It is now proposed to introduce a new constant of static stability, K_s, which will have a more logical relationship to a desirable period of oscillation.

Thus, if one writes:

$$\frac{dM_{c.g.}}{d\theta} = K_s K_B \cdot qSc$$

$$\frac{\partial M}{\partial \theta} \propto \frac{1}{m} K_s K_B \cdot qSc \propto K_B c$$

and for the pitching equation with only static stability considered, the period of oscillation

$$P \propto \sqrt{\frac{1}{M_\theta / K_B^2}} \propto \sqrt{\frac{K_B^2}{K_B c}}$$

will tend to be independent of linear dimensions, density, or loading per square foot—which is a desirable objective within certain limits.

Design on this basis would amount to increasing the static stability not as rapidly as the linear dimensions, but more in proportion to the radius of gyration—which in reality does increase less rapidly than the linear dimensions; because:

$$\text{Mass} \propto l^3$$
$$\text{Moment of Inertia} \propto l^4$$

Thus

$$K_B \propto (\text{Moment of Inertia/Mass})^{1/2} \propto l^{1/2}$$

These relations, of course, are all approximate. Furthermore, it is certainly not on the static stability alone that the period of oscillation depends, and the above arguments are merely approximations.

A Proposed Damping Coefficient

From the pitching moment equation with only damping considered, it appears that the time to damp to half amplitude is inversely proportional to M_q/K_B^2. From derivative relationships it is also apparent that:

$$\frac{M_q}{K_B^2} \propto \left(\frac{\rho}{w}\right)^{1/2}$$

Thus it can be said:

$$\frac{M_q}{K_B^2} = K_{q_1}\left(\frac{\rho}{w}\right)^{1/2}$$

This is equivalent to writing:

$$\frac{\eta\rho l_t^2 S_t U \dfrac{dC_{Lt}}{d\alpha_t}}{mK_B^2} = K_{q_1}\left(\frac{\rho}{w}\right)^{1/2}$$

From Table 2, it can be seen that current practice does give K_{q1} a substantially constant value for a variety of airplanes.

This is equivalent to saying that current practice falls in the same category as when: $\dfrac{dM_{c.g.}}{d\theta} = K_A q S c$, is employed to determine the static stability. All airplanes tend to be similar as far as the damping over moment of inertia ratio is concerned. But this does not mean that such procedure is correct.

If $\dfrac{M_q}{K_B^2} = K_{q_1}\left(\dfrac{\rho}{w}\right)^{1/2}$ were the guiding equation, then heavily loaded airplanes would tend to be less damped, and airplanes flying at high altitudes at the same attitude would tend to be less damped, but the designer, seeking to maintain the satisfactory longitudinal motion of a prototype and passing to a heavier loading, should in reality endeavor to keep the ratio M_q/K_B^2 a constant.

The damping equation should, therefore, be of the form:

$$\frac{\eta\rho l_t^2 S_t U \dfrac{dC_{L_t}}{d\alpha_t}}{mK_B^2} = C$$

Remembering that: $w \propto (m/S)$, and $U \propto (w/\rho)^{1/2}$, the above equation can be readily transfered into the form:

$$\frac{S_t}{S_w}\cdot\left(\frac{l_t}{K_B}\right)^2 \frac{dC_{L_t}}{d\alpha_t} = K_{q_2}\left(\frac{w}{\rho_r}\right)^{1/2}$$

It is K_{q_2} of the above equation which is suggested as a new damping constant, because it will tend to check excessive departure from the normal in damping time. The values of K_{q_2} in Table 2 show wide variation, as would be expected, since K_{q_1} has such closely similar values.

Conclusions

(1) While the desirable characteristics of longitudinal motion are on a none too secure basis, it is clear that the period of the long oscillation should be within certain definite limits of length. The period should neither be so long that there is doubt as to recovery, nor so short as to give the impression of violent, jerky motion. There is also a definite limit to the number of oscillations permissible before the motion becomes imperceptible.

(2) The way to define longitudinal stability quantitatively is with reference to time; duration of the period, duration of the time to damp to half amplitude, and ratio of time to damp to the period.

(3) If it is conceded that longitudinal stability should be defined in terms of periods of oscillation and times to damp to half amplitude, then the simple use of Diehl's Coefficient of static stability is not adequate, and the designer should make at least some attempt to go a little deeper into the subject.

(4) Consideration should be given to the effects of linear dimensions, wing loading, and air density, and the practical approach in design would be to start with an airplane whose longitudinal stability characteristics are known, and known to be satisfactory, and to make allowance for variations in the above parameters when passing to a new design.

(5) The effect of increasing the linear dimensions is to decrease to effective static stability while leaving the damping unchanged. Therefore, in passing to a larger machine, the designer should seek to increase the static stability by moving the center of gravity forward, for example, without laying stress on increased tail area or increased length of tail arm.

(6) The effects of increasing the wing loading or decreasing the air density are interchangeable, and

lead to a shorter period and longer damping time. In passing to heavier loadings, the tendency should be to increase the area of the tail surfaces or the length of tail arm, rather than to increase static stability by moving the c.g. ahead, for example.

(7) The effect of increasing the radius of gyration is to increase both the period of oscillation and the time to damp to half amplitude, but the effect on the time to damp is much more pronounced.

(8) In studying the effects of simultaneous changes in linear dimensions, wing loading, and density, it is not necessary to resort to non-dimensional coefficients and hypothetical machines. By the introduction of a single new parameter or other simple methods, it is possible to investigate such changes rapidly, beginning with a machine of definite characteristics.

(9) From routine wind-tunnel tests of a new model, provided they include two angular settings of the tail surfaces, and preferably two lengths of tail arm, it should be possible to arrive at a complete practical exploration of the longitudinal motion of a new airplane (without power).

(10) If empirical coefficients are employed in design then there should be two coefficients: one a static stability coefficient and one a damping coefficient.

(11) Neither the non-dimensional aerodynamic coefficient of static stability nor the Diehl Constant is logical, since neither takes due cognizance of the various factors involved.

(12) While the importance of the static stability is somewhat exaggerated, Diehl's Constant has the great defect of making the static stability appear unduly high for a heavily loaded machine, while not revealing the possibly unduly low static stability of a machine of very large dimensions.

(13) The new stability coefficient, K_s, may therefore be an improvement since it has a somewhat better physical basis.

(14) Damping and time to damp to half amplitude must be taken into account in even the most practical design work; hence a new damping coefficient K_{q_2} is suggested which has a definite physical basis.

(15) With numerical values obtained from actual experience, these two new constants should enable at least preliminary evaluation of the longitudinal motion to be made.

Book Review

Armada of the Air, by NORMAN BENTLEY; Lothrop, Lee & Shepard Co., N. Y., 1937; 245 pages, $2.00.

This is a book which will appeal to the young boy or girl who looks on aviation as a romantic adventure. A "typical vision of English girlhood" who is a pilot, assists an "altogether marvelous and adorable young man" who is also a pilot, to perfect a device that stops aircraft motors when they pass over a system of wires. By their invention they are able to prevent the consequences of an attack on England by four European dictatorships and cause twenty-five thousand attacking airplanes to land and become the counter attacking air force which subdues the enemy. It is full of intrigue, plots, and counterplots and will please those who like their aviation surrounded by heroics.

New Airplane Performance Slide Rule

W. C. ROCKEFELLER, *California Institute of Technology*

Presented at the Airplane Stability and Performance Session, Fifth Annual Meeting, I. Ae. S. January 29, 1937

IN THE calculation of airplane performance, there has been a comparatively large number of charts used which, since the accuracy required in these calculations is relatively great, are often large and therefore inconvenient to use. A large number of the calculations are identical except for numerical values. For this reason, the author felt that a slide rule should be devised by means of which calculations which are often repeated could be done rapidly and conveniently.

In the calculation of airplane performance, there are always two major factors which must be considered. The first deals with the power-required characteristics. It is generally felt that the power-required characteristics of any airplane flying within a reasonable range of speeds, are quite well understood, and knowing the fundamental parameters which define these characteristics, we can predict the power required with reasonable accuracy. The second factor deals with the power-available, which depends upon the engine-propeller combinations. The characteristics of this group are not so well understood, nor are the results in the form of power available obtainable by prediction with the same accuracy as in the case of the power required. Furthermore, the characteristics of these units seem more likely to change from time to time, either when new and more accurate experimental work is done on previous propeller-blade forms, or when new propeller units are designed, thus changing the characteristics.

In designing a slide rule, it is essential that all information placed on it be of such a nature that it will not have to be changed from time to time. For this reason, it becomes apparent that only those portions of the performance which depend upon the power-required characteristics of the airplane can be placed on the rule. In order to make the rule useful, it is necessary that these data of power required be presented in such form that the particular power-available data in use at that time can be introduced into the calculations simply and speedily. The form of the performance equations necessary to accomplish this purpose is included in another paper by the author.[1] It is the object of the slide rule to eliminate the charts which are necessary in making these calculations by the method in the reference just mentioned.

The basic parameter used throughout the calculations is the parameter Λ_σ, which is used as the base for the slide rule. The parameter is defined by

$$\Lambda_\sigma = (1/\sigma)^{2/3}\Lambda = (1/\sigma)^{2/3}\, l_s l_t^{4/3}/l_p^{1/3} \tag{1}$$

where

$$\begin{aligned} l_s &= W/e(kb_1)^2, \\ l_t &= W/\eta \text{ b.hp.}, \\ l_p &= W/f. \end{aligned} \tag{2}$$

Fig. 1 shows a photographic reproduction of the scales used on this slide rule. The rule is built with central sliding scales bounded on either side by stationary scales. Both sides of the rule are used and each side is reproduced separately in the figure.

In order to calculate Λ_σ, it is first necessary to calculate the loading parameters l_s, l_p, and l_t.[1] This requires simple multiplication and division scales similar to the common C and D scales on the normal slide rules. These two scales appear on the front face of the slide rule and are labeled l_s and Λ. To calculate Λ, two additional scales are provided, labeled $l_p^{1/3}$ and $l_t^{4/3}$. By using the four scales just mentioned, Λ can be computed easily. In order to calculate Λ_σ, it is necessary to provide a scale giving $(1/\sigma)^{2/3}$, which is defined by reference to the standard altitude as given.[2] This scale appears on the back of the rule and is labeled $(1/\sigma)^{2/3}$. This scale, used in conjunction with the Λ scale, allows the calculation of Λ_σ to be made quickly.

To calculate the velocity of the airplane in level flight, it is necessary to know first, the effect of the parasite drag, and then, the effect of the induced drag. The equation for the velocity (m.p.h.) is:

$$\begin{aligned} V &= V_p\Omega_\sigma \\ &= 52.73 \left(\frac{1}{\sigma}\frac{l_p}{l_t}\right)^{1/3} \Omega_\sigma, \end{aligned} \tag{3}$$

where Ω_σ is defined in reference 1 by the equation

$$\Lambda'_\sigma = \Omega_\sigma(1 - \Omega_\sigma^3). \tag{4}$$

The first group of terms of Eq. (3), *i.e.*, all except Ω_σ, gives the speed V_p which the airplane would have in level flight if there were no induced drag. The factor Ω_σ gives the fraction of the so-called parasite speed to which the actual speed is reduced by reason of the induced drag. The solution of Eq. (4) appears directly below the Λ_σ scale on the back of the rule. To find Ω_σ, it is merely necessary to set the hairline on the proper value of Λ_σ and read the corresponding value of Ω_σ. On the Λ scale of the rule, there is drawn a special line

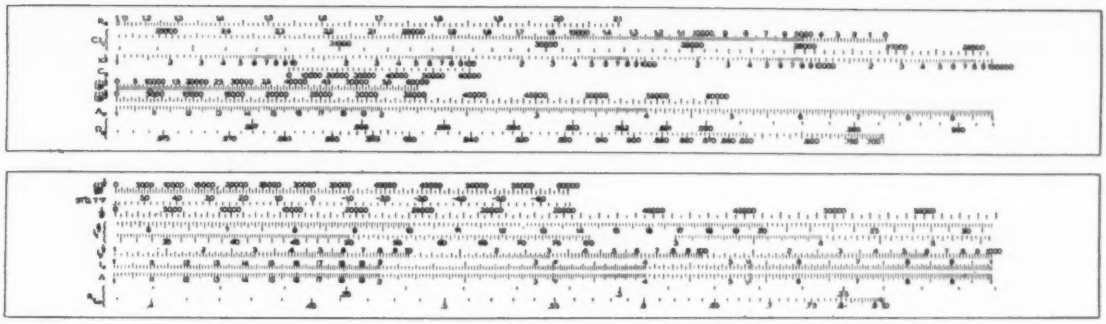

FIG. 1.

at 52.73 which is the numerical factor appearing in Eq. (3).

In calculating the speed for maximum rate of climb, it is first necessary to calculate the theoretical speed for minimum power required, as shown in reference 1. The equation for the ratio of the speed for minimum power required to the maximum speed, $R_{V_{MP}}$, is

$$R_{V_{MP}} = \left[\frac{\Gamma_\sigma}{3(1-\Gamma_\sigma)}\right]^{1/4} \tag{5}$$

where Γ_σ is defined by the equation

$$\Lambda'_\sigma = \Gamma_\sigma(1-\Gamma_\sigma)^{1/3} \tag{6}$$

Thus $R_{V_{MP}}$ is a function of Λ_σ only, and can be determined if Λ_σ is known. The scales representing the solution in this equation appear on the front face, directly below the Λ scale, and here again, the upper scale corresponds to Λ_σ's ranging from 1 to 10, and the lower scale from 10 to 75.

After having found the ratio, R_R, between speed for maximum rate of climb and the speed for minimum power required, by the means given in reference 1, it is necessary to calculate the new value of Λ_σ which must be used in the maximum-rate-of-climb equation. The ratio of these two values of Λ_σ to R_Λ is given by equation

$$R_\Lambda = \left[\frac{R_R^4+3}{4R_R}\right]^{4/3} \tag{7}$$

and this is presented at the top of the back face of the rule, labeled R_R. The value of R_R on this scale corresponds to a value of R_Λ on the Λ_σ scale on the same side of the rule. Multiplying this value of R_Λ by the value of Λ_σ for high speed, gives the value of Λ_{σ_C} for climb, after having made the necessary correction for the power variation. The maximum rate of climb is then defined by the equation

$$Cl_t = 3{,}3000 - 1294\,\Lambda_\sigma^{3/4} \tag{8}$$

and values of Cl_t are indicated near the top of the back face of the rule and correspond to values of Λ_σ given on the Λ_σ scale. The lower Cl_t scale corresponds to Λ_σ's from 1 to 10, and the upper scale from 10 to 75.

The above are the basic scales necessary from the standpoint of the airplane. To calculate the power available, it is necessary to determine the values of the dimensional parameters C_s, speed-power coefficient, and J, the advance ratio, (or some similar coefficient) where

$$C_s = \frac{0.638\,\sigma^{1/2}\,V}{(\text{b.hp.})^{1/2}\,(\text{r.p.m.})^{1/2}}. \tag{9}$$

Two scales at the top of the sliding scales on the back of the rule are provided for the calculation of C_s. Calculation of J may be made on the l_s and Λ scales on the front of the rule.

There are many more calculations which can be made with the scales described, and, as a matter of fact, any performance calculation dealing with normal performance characteristics, partial engine performance, etc., can be calculated by means of the scales given without the aid of any charts except those dealing with the power-available phase of the problem. Scales of this slide rule replace some twenty to twenty-five charts which are normally necessary.

Another use of this rule lies in the reduction of flight-test data. For convenience in so doing, two more scales are provided. $(1/\sigma)^{1/2}$, when multiplied by the indicated air speed, gives true air speed as given by

$$V = (1/\sigma)^{1/2}\,V_{ind.} \tag{10}$$

Since it is seldom that flight tests are made at standard altitude conditions, it is necessary to provide for the reduction to standard altitude. The principal reduction is one of density and is given by

$$(1/\sigma) = (1/\sigma)_s(T/T_s) \tag{11}$$

where T_s and $(1/\sigma)_s$ are the absolute temperature and inverse density ratio for the standard atmosphere, and T and $(1/\sigma)$ the same quantities encountered during the particular flight test. The scale of standard temperature in degrees Fahrenheit absolute is presented in one of the upper scales on the front face, and the altitude

corresponding to these temperatures is given by the $(1/\sigma)^{1/3}$ scale.

Other problems which may be solved are shown by examples in reference 1. It is felt that this rule will replace a large amount of the routine calculations required in the past by reason of the multitude of charts necessary.

REFERENCES

[1] W. C. Rockefeller, *General Airplane Performance.* (To be published).

[2] Walter S. Diehl, *Standard Atmosphere—Tables and Data,* N.A.C.A. Technical Report No. 218.

[3] W. Bailey Oswald, *General Formulas and Charts for the Calculation of Airplane Performance,* N.A.C.A. Technical Report No. 408.

Book Reviews

Navy Wings, by LIEUTENANT HAROLD BLAINE MILLER, U. S. N.; Dodd, Meade & Company, Inc., New York, 1937; 323 pages, ill., $3.00.

This is a readable history of the aeronautical activities of the United States Navy. Lieutenant Miller, who is in active service as a pilot on the U.S.S. *Salt Lake City,* has spent six years in collecting information regarding Naval aviation and this book is one of the results. Another was a comprehensive chronology of naval aviation which was prepared last year in the offices of the Institute.

The author deserves the greatest credit for his frankness in compiling the earlier history of the U. S. Navy's activity, or rather inactivity, in its use of the airplane. Those who remember the disheartening treatment of air enthusiasts by Secretary Daniels and Admiral Benson will find that Lieutenant Miller has not glossed over these difficult times. As late as 1925 and just before the Morrow Board, Lieutenant Miller writes, "In spite of the very definite and logical trend of the development of naval aviation there still remained no specific direction nor a tangible goal." But the book closes on a high note. Our naval air force leads the world today and possibly all the trials and discouragements of the early days will only reflect greater credit on the early aviation pioneers in the Navy who fought for their adopted profession.

As the history of naval aviation for the past ten years is well known to every reader of the daily newspapers, Lieutenant Miller rightly devotes his attention principally to the earlier phases of the employment of airplanes and sea going aircraft for naval purposes. The work at Hammondsport, North Island, Pensacola and other stations is vividly described with interpretive comment which gives a reader an insight into how naval aviation was created. The development of the catapult, deck landing gear, etc., which lead up to the aircraft carrier and airship hook-on are all considered from the operator's point of view.

Perhaps the part of the book that will be most treasured is that dealing with men whose names will always remain honored in the history of aeronautics. Ellyson, Rodgers, Towers, Moffett, and dozens of others are portrayed in a way that only a well-informed friend could write.

The gradual evolution of a naval aviation policy is traced painstakingly but always in a most entertaining manner. If the book has faults they are of omission. In particular, members of the Institute will have to pardon the author's treatment of important engineering developments that appeared almost like rabbits out of a hat, when desired by executive officers with funds in hand. Obviously there was developed a very competent aeronautical engineering organization in the Navy during these same years. The story of this development would require another book, however. A good table of contents and an index would make the book more easily searched.

Aircraft Materials and Processes, by GEORGE F. TITTERTON; Pitman Publishing Corporation, New York, 1937; 328 pages, ill., $3.50.

Even a casual perusal of this book marks it as the work of an observer with adequate background for his assignment. The author apparently draws heavily upon his own practical experience, which has specifically fitted him for writing a book of this nature.

The work is a comprehensive and well coordinated discussion of all materials used in aircraft construction as well as the various processes involving their uses. The wide range of the book naturally precludes going into great detail but the author approaches the subject from a practical standpoint, omitting unimportant details and presents it in sufficient detail to make it a very clear and readable book, which should be equally valuable to executives, engineers, designers, inspectors, and practical shop men concerned with the subject matter.

Of particular interest was the chapter on heat treatment. This subject is covered very thoroughly considering the space alloted, both as to theory and practice and should be very beneficial to both engineers and practical men. The author presents a complete picture without unimportant details to mar its clarity and although in book form, it is so concise and so well coordinated that it can readily be used as a quick reference book when needed.

The chapter on properties and uses of aircraft steels should be particularly helpful to the aircraft designer as it shows in a condensed form the capabilities of all commonly used steels, giving their mechanical properties, form in which material is available, general use of each material, and the general characteristics as regards to machining, welding, forming, etc. This chapter and the one on selection of materials, which enumerates the points to be considered in selecting a material from the standpoint of economy and engineering considerations, should make the book a valuable and indispensable addition to the well-equipped library of every aircraft engineering department.

Although written primarily for the aircraft industry, the book contains much to recommend it to all those dealing with the various materials discussed and their applications. Particularly is this true about the information pertaining to the more recent developments of various alloys as well as their applications. This is information not readily found in books of such a general nature.

REID B. GRAY
Glenn L. Martin Company

Speculations on Propellers for Stratosphere Airplanes

SHATSWELL OBER, *Massachusetts Institute of Technology*

(Received June 4, 1937)

SUMMARY

This note shows that a propeller can be designed to give satisfactory aerodynamic characteristics for flight at 50,000 ft., that it will give relatively poor performance at low altitudes, that take-off will be fair, but that the weight will be excessive. Diameters are found by $D = K_1\sqrt{\text{b.hp.}/\sigma}$ where K_1 depends on the tip speed, forward speed, number, and shape of blades.

ONE of the many difficulties that must be overcome before airplanes can take advantage of the stratosphere is presented by the propeller. First attempts to design a propeller lead to excessive diameter and weight, and to a form hardly satisfactory for climbing to the operational altitude. The object of this note is to show how serious this difficulty is when the altitude is really high. A simple scheme for selection of propeller diameters is included.

The power output of the engine may be maintained at sea level value by supercharging, but no such scheme is available for the propeller. The propeller must operate in the atmosphere as it finds it. Properties of the atmosphere which affect the operation of the propeller are the density (thrust and power vary directly as the density), the kinematic viscosity (this determines the Reynolds Number), and the temperature (this fixes the speed of sound hence the compressibility effect). The variation of these properties with altitude is given in Table 1, based on the N.A.C.A. standard atmosphere[1] and extended to higher altitudes on the assumption that the temperature throughout the stratosphere is −67°F.

In Table 1 only the two highest altitudes are in the stratosphere, though flight at about 25,000 ft. is often loosely called "stratosphere" flying. While flight at 75,000 ft. is beyond the realm of practicability at present, the data there are included to show how little air is available for the propeller and airplane to use. The design of a propeller for an airplane flying at 50,000 ft. will first be considered. The air density here is less than one-sixth that at sea level and the tip speed must be restricted to seven-eighths that allowable at sea level in order to avoid loss in efficiency due to compressibility. The Reynolds Number will be less than one-fifth that at sea level causing an appreciable but not too serious increase of profile drag coefficients of the blade sections.

The limiting factor for the operation of an airplane propeller, except for engines of very moderate power

[1] Walter S. Diehl, *Standard Atmosphere—Tables and Data*, N.A.C.A. Technical Report No. 218, 1925.

TABLE 1

Altitude	P	σ	T	ν	C	R.N.
0	760	1.000	59	.000157	1120	2,200,000
10,000	523	.738	23	.000202	1080	1,700,000
25,000	282	.448	−30	.000304	1020	1,200,000
50,000	87	.152	−67	.000842	970	400,000
75,000	27	.047	−67	.00273	970	130,000

Altitude—feet
P = pressure, millimeters of mercury.
σ = ratio of density to that at sea level, .002378 slugs per cubic foot.
T = temperature, °F.
ν = kinematic viscosity, ft.² per sec.
C = viscosity of sound, ft. per sec.
R.N. = Reynolds Number for a 6 in. chord section at 700 ft. per sec. velocity.

near sea level, is the tip speed, which must be kept below .9 the speed of sound, to avoid difficulties arising from the compressibility of the air. In the stratosphere the tip speed will be the limiting factor for all cases. By tip speed is meant the relative speed of the tip through the air along a helical path, not the peripheral speed at the tip. The tip speed at high air speeds may be 1.2 times the peripheral speed, so the allowable peripheral speed is about .75 that of sound. The speed of sound in the stratosphere is about 970 ft. per sec., three-quarters of that is 730; to allow some reserve, the peripheral speed will be kept constant at 700 ft. per sec. This limitation of the peripheral speed rather than of the tip speed is merely a matter of convenience that introduces little error, since only high speed in the stratosphere is of interest. Fixing the peripheral speed necessitates change of the engine gear ratio with power at constant altitude, and with altitude at constant power.

With the peripheral speed fixed, the forward speed V fixes the advance ratio, V/nD. This in turn determines the blade angle setting to obtain the highest possible efficiency for propellers of any one type, and the corresponding power coefficient

$$C_P = \frac{\text{b.hp. } 550}{\rho\, n^3\, D^5}$$

Since the peripheral speed is fixed nD will be constant, and $D = K\sqrt{\text{b.hp.}/\sigma}$, in which K includes standard density, the constant value of nD, the 550, and the value of C_p. The last depends only on V for one type of propeller; more generally on the blade

shape and number of blades. The value of K may be computed for an assumed peripheral speed for any family of propellers for which test data are available.

Propeller test data to be used in determining the optimum blade angle for any set of operating conditions are best presented as charts of efficiency (η) and V/nD (J) plotted against the "speed power" coefficient[2] (C_s). On such charts a curve may be drawn showing the variation of J with C_s for highest efficiency. This curve may be approximated by the straight line, $J = a\,C_s - b$. For two bladed metal propellers of moderate width,[3] $J = .66\,C_s - .14$. For four bladed metal propellers with wide blades,[4,5] $J = .89\,C_s - .24$. Writing for C_s its value in "engineering units,"

$$J = \frac{.638\,a\,V}{\left(\frac{\text{b.hp.}}{\sigma}\right)^{1/5} N^{2/5}} - b$$

where V is in m.p.h. and N is equal to r.p.m. With the peripheral speed (πnD) 700 ft. per sec., ND = 13,360, and this equation becomes

$$J = \frac{88\,V}{13{,}360} = \frac{.638\,a\,VD^{2/5}}{\left(\frac{\text{b.hp.}}{\sigma}\right)^{1/5} 13{,}360^{2/5}} - b$$

from which,

$$D = K_1 \sqrt{\frac{\text{b.hp.}}{\sigma}}$$

K_1 is a "constant" varying slowly with V for any fixed values of a and b.

For blades of moderate width, the unique relation between forward speed and blade angle measured at .75 tip radius, given by fixing the peripheral speed at 700 ft. per sec., is:

V (m.p.h.)	100	200	300	400
Blade angle	20°	32°	42°	51°

For the wide blades the angle for best efficiency is one or two degrees greater.

The expression which has been derived above shows that the diameter of a propeller of one type must vary inversely as the square root of the density if it is to absorb the same power at different densities. Thus at 50,000 ft. the diameter must be 2.6 times that at sea level, and at 75,000 ft., 4.6 that at sea level, the power being maintained constant.

[2] Fred E. Weick, *Aircraft Propeller Design*, p. 91, McGraw-Hill Book Company, New York, 1930.

[3] *Ibid.*, page 271.

[4] C. N. H. Lock, H. Bateman and H. L. Nixon, *Wind Tunnel Tests of High Pitch Airscrews*, Aero. Res. Com. R. & M. 1673, 1934.

[5] In using the data of reference 4 which are for isolated propellers, no changes in blade angle have been made, but the efficiencies have been reduced 5 percent in estimating propulsive efficiencies.

TABLE 2

Values of K_1 for Blades of Moderate Width
Peripheral Speed—700 ft. per sec.

V (m.p.h.)	J	2 blades	3 blades	4 blades
100	.66	.67	.56	.50
150	.99	.57	.48	.43
200	1.32	.53	.44	.39
250	1.65	.51	.42	.37
300	1.98	.49	.41	.36
350	2.31	.48	.40	.35
400	2.64	.47	.39	.35

K_1 for three blades is estimated by assuming the b.hp. to be 1.43 that for two blades; for four blades assuming the b.hp. to be 1.82 that for two blades. Both assumptions are justified by tests.

TABLE 3

Values of K_1 for Extra Wide Blades. (700 ft. per sec.)

V (m.p.h.)	4 blades	6 blades
100	.43	.36
200	.29	.25
250	.27	.23
300	.26	.22

K_1 for 6 blades is estimated by assuming the b.hp. to be 1.43 that for four blades.

If the blades and hubs of geometrically similar propellers of different diameters are of the same material, the weight of the entire propeller will vary as the cube of the diameter. Since the major steady load on a thin metal propeller is that due to the centrifugal force it is reasonable to assume that the blades of different diameter propellers will be geometrically similar. As the blade size increases, the type of construction may possibly be changed to permit use of a more hollow blade. Weight saving by this scheme is neglected. The question for the hub is not so simple but the assumption of geometrical similarity should not be far wrong. Basic weights are assumed for 12 ft. diameter propellers, all with controllable pitch, as follows:

3 bladed, moderate width, light alloy	330 lbs.
3 bladed, moderate width, "wood"	about 200 lbs.
4 bladed, extra width, light alloy	about 650 lbs.
6 bladed, extra width, light alloy	about 900 lbs.

Of these figures the first is about ten percent lower than current practice, the others are approximations made in lieu of reliable information. On these assumptions, a six bladed metal propeller with wide blades will weigh half as much as the three blader of moderate width absorbing the same horsepower. It should be noticed that the assumption of variations of propeller weight with the cube of the diameter, combined with the variation of the diameter with $\sqrt{\text{b.hp.}}$ at fixed density, means that the weight will vary as $(\text{b.hp.})^{3/2}$. The

TABLE 4

Altitude	V	C_L	C_D	J
10,000	202	.33	.023	1.33
25,000	232	.41	.025	1.53
50,000	284	.79	.040	1.87

TABLE 5

Blades	K_1	Diameter	Weight	R.p.m.	Blade Angle
3 medium	.41	26	3300	510	40°
4 wide	.26	16	1500	840	41+°
6 wide	.22	14	1500	950	41°

weight per horsepower will vary as $\sqrt{\text{b.hp.}}$ as long as the tip speed is held constant.[6]

A study of results of tests of two or three bladed propellers of the moderate width family shows that for the three bladed propellers the propulsive efficiency when the blade setting at .75 tip radius is 30° or over, will be at least .83. The isolated efficiency of the propellers with six wide blades is estimated from tests on two and four bladed propellers as .83. The propulsive efficiency should be about .80 for propellers of over 30° blade angle.

The significance of these estimates of weights, diameters, and efficiencies may best be appreciated by an example. Consider an airplane weighing 25,000 lbs., wing area 1000 sq. ft., minimum parasite drag coefficient based on the wing area .020, Oswald's efficiency factor .90. It will have two engines, each capable of giving 600 b.hp. for cruising regardless of the altitude. Flight at maximum L/D will give the highest possible cruising speed with a fixed thrust horsepower and the altitude corresponding may be called the "optimum" altitude. At this optimum altitude the drag coefficient of the airplane will be twice the minimum parasite drag coefficient, or for the example .040. For any given values of minimum parasite drag coefficient and airplane efficiency factor, the optimum altitude depends only on the aspect ratio. The aspect ratio for given altitudes, and speeds attainable with 960 t.hp. follow:

Optimum altitude (ft.)	10,000	25,000	50,000	75,000
Aspect ratio	3.9	5.4	11.1	24.4
Cruising speed (m.p.h.)	169	198	284	420 (?)
Indicated airspeed (m.p.h.)	145	132	111	91

These are four different airplanes, and the high altitude ones would make better speed at low altitude than the low optimum altitude ones do. The 50,000 ft. airplane will be used for the example. To study the stratosphere propeller at low altitudes, the high speeds of this airplane at several altitudes will next be found (Table 4), assuming that there will be 960 t.hp. available at all altitudes.

Three propellers will be selected (Table 5) to suit the conditions at 50,000 ft. using values of K_1 from Tables 2 and 3. The propeller must absorb 600 b.hp. at 700 ft. per sec. peripheral speed at 50,000 ft. where the density ratio is .152. Weights are for metal propellers.

Diameter, weight, and low rate of rotation all indicate that the three bladed propeller is not possible. The six bladed propeller is best from the standpoint of diameter and weight but added constructional difficulties of the controllable hub make it less desirable than the four bladed one. It is not at all certain that this four bladed propeller and its engine with gears to give, say, 3:1 reduction can be considered as within practical weight limits, but nothing more interesting appears. The weight of a celluloid-protected, wooden, four bladed propeller would be perhaps 800 lbs. However, such propellers do not yet exist in the required diameters.

For cruising at lower altitudes or for climbing to the stratosphere the propeller will be turned to lower blade angles. Since the operating altitude is so high, the change in blade angle required will be excessive and a type of control mechanism moving the blades through gears rather than levers may be needed. The blade angle to allow the engine to turn the propeller at desired revolutions will be below that of best efficiency, with resulting loss in efficiency. The efficiency falls off rapidly as V/nD is increased beyond that of maximum efficiency.

For example, cruising at 10,000 ft. the blade angle for the "stratosphere" propeller would be 27°, whereas to give best efficiency the blade angle should be 35°. A loss of 10 percent in efficiency results, and the cruising speed would be some 10 m.p.h. less than given in Table 4 for 960 t.hp.

At sea level, cruising speed is not important, but there must be ample thrust for take-off and a good rate of climb. Full power, to be used in climb, will be assumed as 900 hp. per engine at 960 propeller r.p.m. Take-off power of 1080 hp. at 1050 r.p.m. will be assumed. Propeller diameter is large, blade angle to allow full r.p.m. will be under 12°, therefore the static thrust will be ample. At 100 m.p.h. the blade angle will be about 12°, the efficiency .60 with the propeller operating at a V/nD greater than that of maximum efficiency. Best efficiency at that speed would be about .66. Climbing at 110 m.p.h., using full power, the blade angle would be about 14°, efficiency .60, propeller operating beyond maximum efficiency (best efficiency .70), rate of climb 940 ft. per minute. Take-off and climb should be satisfactory.

The stratosphere propeller is more satisfactory for take-off than a propeller designed to give 250 m.p.h. at low altitude, say 10,000 ft. The reason for this is

[6] This weight variation has been mentioned several times by previous writers. The particular method of finding diameters is believed to be new.

that when high blade-angle propellers are used near sea level the power coefficient is so large that the smallest possible blade angle to prevent over-speeding of the engine is much too large for best take-off. There is actually a "best" altitude for any desired cruising speed with propellers of one family. For example, with the wide bladed four bladed propellers[2] for 250 m.p.h., the "best" altitude is around 29,000 ft. For that speed, lower operational altitudes lead to low static thrust and poor take-off, higher altitudes to poor low altitude cruising speeds and climbs. These losses could be avoided by using propellers of variable area or diameter, or engines with variable reduction gear ratios.

This discussion of a 16 ft., four bladed, controllable pitch propeller on a 600 hp. engine on a stratosphere airplane shows that there are no insurmountable aerodynamic troubles. Low altitude performance is not good but is fairly satisfactory. The propeller is not different enough from the usual to make one anticipate any serious difficulties in manufacture. The four bladed hub is outside the range of our propeller manufacturers' experience, but certainly within their ability. The real trouble is the weight that accompanies the necessarily large diameter. The propeller weight on say a Douglas DC-3 is about 3 percent of the total while on the stratosphere airplane studied, it would be about 14 percent of the total without extra allowance for increased engine weight to support the heavier propeller and for the larger gear reduction needed. This forces a serious loss in pay load, due to propeller weight increase alone. One can conclude that commercial flight at an altitude as high as 50,000 ft. is today barred by propeller weight even if all the other hindrances were overcome. Halving the weight of the propellers, which might be possible with wooden blades, would not be sufficient to make the weight problem satisfactory. The wooden bladed propellers would need to be thicker; this would reduce the efficiency, perhaps seriously at the low pitch settings at low altitudes, and also would require even lower tip speed to avoid compressibility losses on such thick blades. Practical questions as to the effect of excessive cold and low pressure on the protective coating of the wooden propellers arise. There is no evidence in the realized weights of hollow steel propeller blades to lead one to anticipate halving the weight if such blades were used. Lighter propellers may follow the development of hollow aluminum or magnesium alloy blades, blades made with reinforced synthetic resins or other new materials, but nothing of this sort is available today. The stratosphere airplane of the future seems to depend very much on future developments in the propeller art.

The Variation of Stress in a Tension-Field Beam

H. W. SIBERT, *University of Cincinnati*

(Received April 16, 1937)

THE purpose of this paper is to increase the present meager knowledge concerning the variation of stress in tension-field beams, which at present is limited to two solutions by Herbert Wagner in N.A.C.A. Technical Memorandums 604 and 605. These two cases are for a concentrated load at the free ends of a rectangular and of a trapezoidal beam, the solution for the latter being only an approximate one.*

Consider a cross section of the beam at a distance z from the origin. Let h be the height of the cross section, t the thickness, and τ_y the shearing stress at a point P whose distance from the median line of the beam is y (Fig. 1). If Q is the shear force on the cross section,

$$Q = \int_{-h/2}^{h/2} \tau_y t \, dy \tag{1}$$

Let x be the distance from the origin to point P', the intersection with the median line of the wrinkle through point P, and let τ_c be the shearing stress at point P'. Since P and P' are on the same wrinkle, $\tau_y = \tau_c$. Let β_c be the angle between the median line and the horizontal, let α be the angle which a wrinkle makes with the horizontal, and let $e = 1/(\tan \alpha + \tan \beta_c)$. Note that $e = \cot \alpha$ when the median line is horizontal ($\beta_c = 0$). When the external loads act upward, the wrinkles slope downward to the right. Hence, from Fig. 1:

$h/2 = f(\tan \alpha + \tan \beta_c) = f/e,$
$f = he/2,$
$y/(x - z) = (h/2)/f = 1/e$
$y = (x - z)/e$
$dy = dx/e$

Note that $y = h/2$ and $y = -h/2$ correspond, respectively, to $x = z + f = z + he/2$ and $x = z - f = z - he/2$. Hence Eq. 1 may be written as

$$Q = \int_{z - he/2}^{z + he/2} \tau_c (t/e) \, dx \tag{2}$$

If the beam is trapezoidal, h is a function of z. Let $c = b/2a$. Then from Fig. 2,

$$h = bz/a = 2cz$$

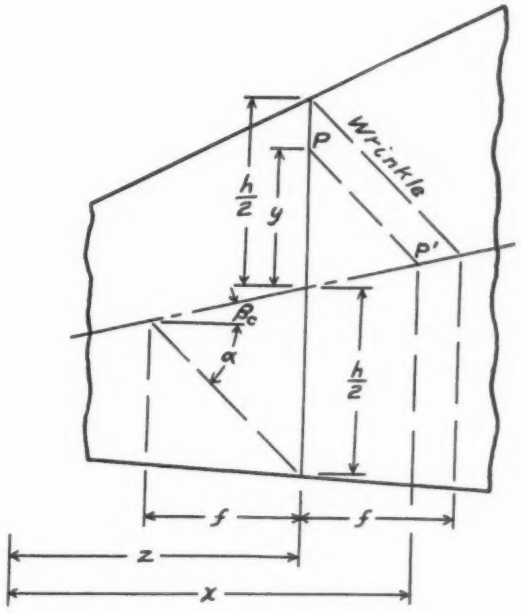

FIG. 1.

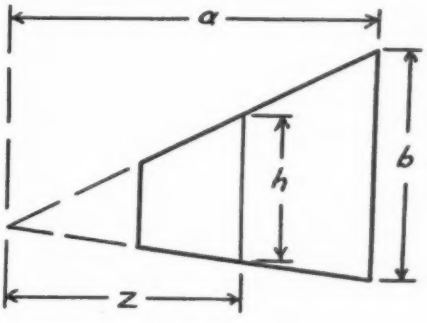

FIG. 2.

Hence

$$z + he/2 = (1 + ce)z$$
$$z - he/2 = (1 - ce)z$$

Thus for a trapezoidal beam Eq. (2) becomes

$$Q = \int_{(1 - ce)z}^{(1 + ce)z} \tau_c (t/e) dx \tag{3}$$

Consider four loading situations:

Case 1: Concentrated up load P at left end.

Case 2: Uniformly distributed up load of w lbs. per in.

* There have been other important contributions to the theory of tension-field beams, namely, N.A.C.A. Technical Memorandums 606 and 809 and two papers by E. H. Atkins in the August, 1936 and January, 1937 issues of Aircraft Engineering. However, none of these articles give solutions for particular loading situations.

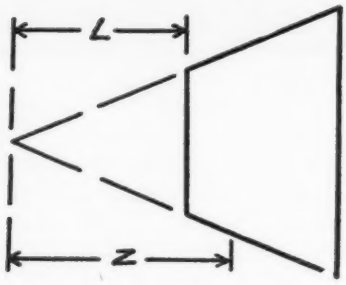

FIG. 3.

Case 3: Uniformly varying up load, $w = mx$.
Case 4: Up load varying as a parabola, $w = mx^2$.

When z is the distance from the free end, the values of τ_c for a beam of constant height which satisfy Eq. 2 are:

Case 1: $Q = P$, $\tau_c = P/(ht)$
Case 2: $Q = wz$, $\tau_c = wx/(ht)$
Case 3: $Q = mz^2/2$, $\tau_c = m(x^2 - h^2e^2/12)/(2ht)$
Case 4: $Q = mz^3/3$, $\tau_c = m(x^3 - h^2e^2x/4)/(3ht)$

For a trapezoidal beam, z is measured from the intersection of the vertex of the trapezoid (Fig. 3). It will be convenient to let $k = 2ce/\log\{(1 + ce)/(1 - ce)\}$, in which log is a natural logarithm. Then the values of τ_c for a trapezoidal beam which satisfy Eq. 3 are:

Case 1: $Q = P$ $\tau_c = Pk/(2cxt)$
Case 2: $Q = w(z - L)$,
$\tau_c = w(x - kL)/(2cxt)$
Case 3: $Q = m(z - L)^2/2$,
$\tau_c = m(x^2 - 2Lx + kL^2)/(4cxt)$
Case 4: $Q = m(z - L)^3/3$,
$\tau_c = m\{x^3/(1 + c^2e^2/3) - 3Lx^2 + 3L^2x - kL^3\}/(6cxt)$

Let Q_x be the shear force and h_x the height at a distance x from the left end of the beam. If x is greater than the length of the beam (as in Fig. 4), Q_x is the shear force and h_x the height with the loading and the beam both extended to a distance x from the left end.

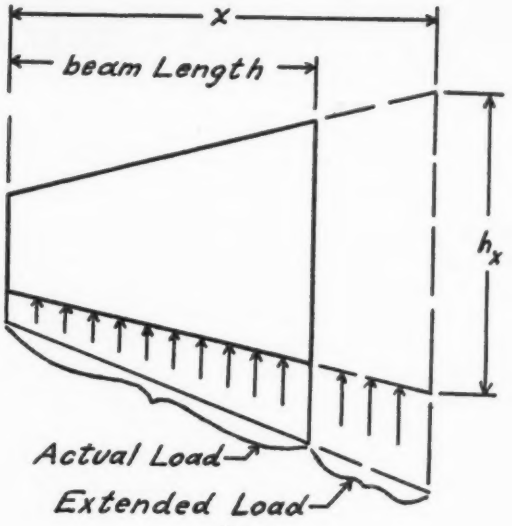

FIG. 4.

For a beam of constant height h_x is constant and equal to h. Hence

Case 1: $Q_x = P$, $\tau_c = Q_x/(ht)$
Case 2: $Q_x = wx$, $\tau_c = Q_x/(ht)$
Case 3: $Q_x = mx^2/2$, $\tau_c = Q_x/(ht) - mhe^2/(24t)$
Case 4: $Q_x = mx^3/3$, $\tau_c = Q_x/(ht) - mhe^2x/(12t)$

Thus it is on the side of safety to assume that $\tau_c = Q_x/(ht)$.

The series expansion for k is

$$k = 1 - c^2e^2/3 - 4c^4e^4/45 + \ldots$$

Usually ce is small enough so that $c^2e^2/3$ and all higher powers of ce are so small compared with unity that they can be neglected. Therefore $k = 1$ approximately; moreover, this approximation is on the side of safety.

Since $h_x = 2cx$ for a trapezoidal beam, one has as a close approximation for such a beam:

Case 1: $Q_x = P$, $\tau_c = Q_x/(h_xt)$
Case 2: $Q_x = w(x - L)$, $\tau_c = Q_x/(h_xt)$
Case 3: $Q_x = m(x - L)^2/2$, $\tau_c = Q_x/(h_xt)$
Case 4: $Q_x = m(x - L)^3/3$, $\tau_c = Q_x/(h_xt)$

Wing Loading

WILBUR C. NELSON, *University of Michigan*

(Received May 14, 1937)

Summary

TWO pertinent topics in the airplane performance field today are those of high-altitude cruising and high wing loading. Many commentators tacitly assume or specifically state that these items are mutually beneficial, while a rigorous investigation will show that this is not true. A study is made here of the proper correlation between wing loading and high-altitude cruising efficiency as applied to the commercial transport field. A wide range of the major performance parameters of span loading, power loading, and drag loading is taken to make the analysis as general as possible. From a study of the charts developed it is obvious that there is a definite, desirable value of the wing loading for any specific altitude cruising condition. Cruising at a 65 per cent power factor and with a power loading of 10 lbs. per b.hp. or more, the optimum wing loading is 25 lbs. per sq. ft. or less at 35,000 ft. altitude, and 20 lbs. per sq. ft. or less at 50,000 ft. altitude for a conventional transport design. Any increase in wing loading above these values should be accompanied by a corresponding decrease in power loading or drag loading, to be aerodynamically sound. Designs considered ranged from 11,000 to 50,000 lbs. gross weight, with power loadings of 8 to 14 lbs. per b.hp. and an aspect ratio of 9.5. The decided penalty of disregarding an optimum wing loading value as the cruising altitude increases is shown. Possibilities of good structural design counterbalancing aerodynamic losses and giving a higher "efficiency factor" at a higher wing loading are briefly discussed. The design problem is approached by a preliminary estimate of the drag, span, and power loadings. A separate evaluation of the wing loading is then made, considering the design altitude cruising conditions instead of determining wing loading simply as the upper limit of a high-lift device.

Introduction

The general increase of aerodynamic efficiency in aircraft design has been accompanied by a gradual increase in wing loading. This increase in wing loading, with its consequent decrease in wing area, results in a direct profile drag reduction which has its effect on performance. Successful application of the split trailing-edge wing flap, with its higher lifts and glide-path control, made possible this trend. At the present time commercial land transport designers in our country have utilized this device to its maximum and are turning toward more effective high-lift, low-drag adaptations to the wing. Fowler flaps, Handley Page slots and flaps, and boundary-layer control are among the more promising possibilities. The former devices have already been applied to existent aircraft both in this country and abroad with more or less success, and the coming year will undoubtedly see a wider application. Improved take-off, climb, ceiling, and increased wing loading are among their potentialities. A discussion of the relative merits involved will not be attempted here. Rather, they will be considered as successfully applied to the ships in question and the problem of an optimum wing loading approached from an altitude cruising viewpoint.

Method of Analysis

The method of analysis used has been to select three typical transport ships of current design (low-wing monoplane, retractable landing gear, conventional nacelles, "clean" exterior) with a feasible range of gross weight and power and to determine their cruising speeds at 65 per cent of the rated power at sea level, 10,000 ft., 35,000 ft., and 50,000 ft. altitudes, with the wing loading varying from 15 to 40 lbs. per sq. ft. Such a procedure obviously involves minor assumptions and approximations which are discussed below. The trends pointed out are more or less obvious qualitatively and it is believed that the quantitative results are not far in error.

A brief analysis of this same design condition has been made by M. E. Gluhareff, in which he discusses aspect ratio and wing loading as separate variables and compares the variation in horsepower required at arbitrary speeds for a particular ship.[1] The main conclusion reached is, that aspect ratio is of great importance in cruising performance with wing loading assuming a minor role. However, in a particular design project the aspect ratio is fixed at an upper limit consistent with structural design and the wing loading then becomes the major variable. In the present paper wing loading and aspect ratio are correlated and a study made on the basis of span loading, using a constant value for the aspect ratio to isolate the wing loading. High wing loading then appears as a definitely undesirable quantity under certain design conditions.

[1] M. E. Gluhareff, *High Altitude Problems*, Journal of the Aeronautical Sciences, Vol. 3, No. 5, page 154, March, 1936.

Due to their intimate structural and aerodynamic relationship, wing and span loading must be considered together. With a constant aspect ratio they become directly proportional: span loading equals wing loading divided by the aspect ratio. The value of 9.5, which has been used in the following examples, is believed an upper limit consistent with current design and construction. Fuselage, nacelles, wing, and tail planform are assumed conventional and the total drag evaluated in view of existent wind-tunnel and flight test data. For the wing, C_{D_P} was assumed as 0.009. Variation of nacelle drag with change in engine diameter and wing area has been based upon GALCIT tests, with nacelle drag coefficients based on frontal area ranging from 0.08 to 0.12.[2] Engine diameters have been selected with regard to current radial designs. After considering the variation in wing and nacelle drag, the balance has been assumed constant for any one ship. This implies the optimistic assumption of no increase in drag due to a high-lift installation, which is to some extent counterbalanced by neglecting variations in tail drag. Equivalent drag areas of 11.49, 20.0, and 45.50 sq. ft. were assumed for the eleven, twenty, and fifty thousand pound ships, respectively. Knowing the drag variation and gross weight, arbitrary values of the wing and power loadings were taken and cruising speeds determined. A chart solution was made, using Oswald's analysis[3] together with Rockefeller's modification.[4] Sea level velocity is determined by a graphical solution of the equation:

$$V = (52.8\, l_p/l_l)^{1/3}(1 - 0.332\, l_s l_t/V)^{1/3}$$

where V is the sea level velocity in m.p.h. under the given drag, span, and power loadings: denoted by l_p, l_s, and l_t, respectively. For a precise formulation of these parameters see reference 3. The airplane efficiency factor was assumed as 0.90 and the propeller efficiency as 0.78. Rockefeller's altitude chart is based upon a *constant thrust horsepower with altitude* and yields a multiplying factor for the sea level velocity to determine the speed at altitude. This factor is plotted against Λ for various altitudes, where

$$\Lambda = l_s(l_l)^{4/3}/(l_p)^{1/3}$$

This assumption of constant thrust horsepower is closely approximated with a supercharged engine and constant speed propeller installation. The problem of power plant and cabin design at high altitudes is treated elsewhere in detail and can only be recognized here as it lies outside the scope of the paper and does not affect any of the conclusions reached.

[2] C. B. Millikan, *On Results of Aerodynamic Research and Their Application to Aircraft Construction*, Journal of the Aeronautical Sciences, Vol. 4, No. 2, page 51, December, 1936.

[3] W. Bailey Oswald, *General Formulas and Charts for the Calculation of Airplane Performance*, N.A.C.A. Technical Report 408.

[4] See reference 2, Fig. 2, page 45.

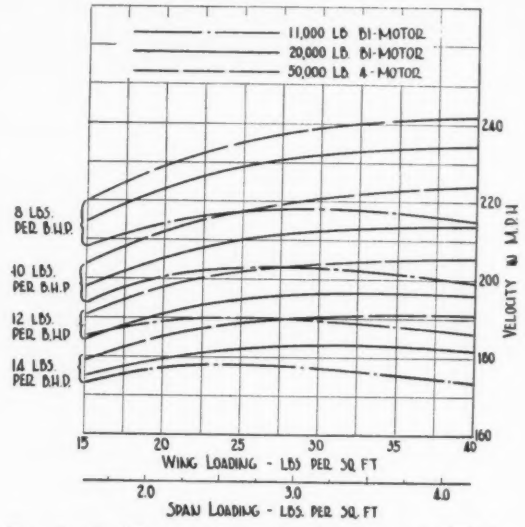
11,000 LB. BI-MOTOR
20,000 LB. BI-MOTOR
50,000 LB. 4-MOTOR
8 LBS. PER B.H.P.
10 LBS. PER B.H.P.
12 LBS. PER B.H.P.
14 LBS. PER B.H.P.
VELOCITY IN M.P.H.
WING LOADING - LBS. PER SQ. FT.
SPAN LOADING - LBS. PER SQ. FT.

FIG. 1. Cruising speed *vs.* wing loading at 10,000 ft. altitude. Low-wing monoplane, aspect ratio 9.5, cruising at 65 percent power.

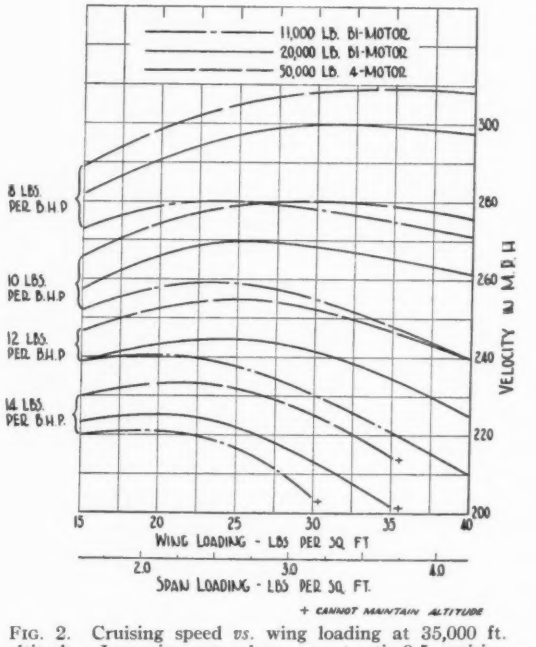
11,000 LB. BI-MOTOR
20,000 LB. BI-MOTOR
50,000 LB. 4-MOTOR
8 LBS. PER B.H.P.
10 LBS. PER B.H.P.
12 LBS. PER B.H.P.
14 LBS. PER B.H.P.
VELOCITY IN M.P.H.
WING LOADING - LBS. PER SQ. FT.
SPAN LOADING - LBS. PER SQ. FT.
+ CANNOT MAINTAIN ALTITUDE

FIG. 2. Cruising speed *vs.* wing loading at 35,000 ft. altitude. Low-wing monoplane, aspect ratio 9.5, cruising at 65 percent power.

DISCUSSION

Considering Fig. 1, which shows the change in cruising velocity at 10,000 ft. due to a variation in wing loading, it will be noted that there is not much advantage to be gained in exceeding a wing loading of 25 lbs. per sq. ft. at a power loading of 12 lbs. per b.hp., or more. A possible exception might be the 50,000 lb. ship For this design the increased overall cleanliness and higher speed at a given power loading

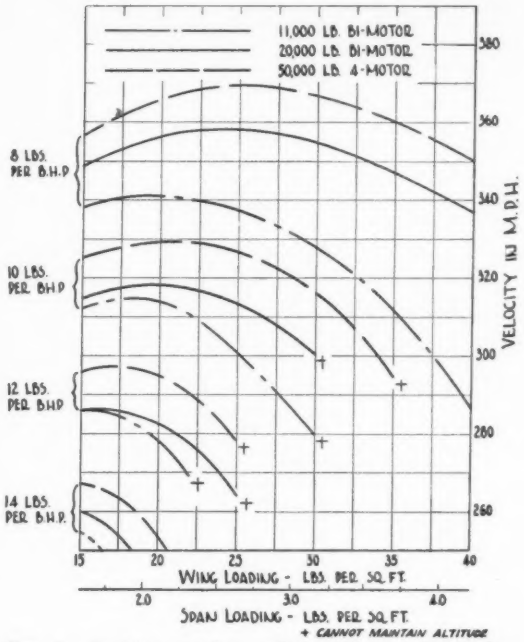
11,000 LB. BI-MOTOR
20,000 LB. BI-MOTOR
50,000 LB. 4-MOTOR
8 LBS. PER B.H.P.
10 LBS. PER B.H.P.
12 LBS. PER B.H.P.
14 LBS. PER B.H.P.
VELOCITY IN M.P.H.
WING LOADING - LBS. PER SQ. FT.
SPAN LOADING - LBS. PER SQ. FT.
+ CANNOT MAINTAIN ALTITUDE

FIG. 3. Cruising speed *vs.* wing loading at 50,000 ft. altitude. Low-wing monoplane, aspect ratio 9.5, cruising at 65 percent power.

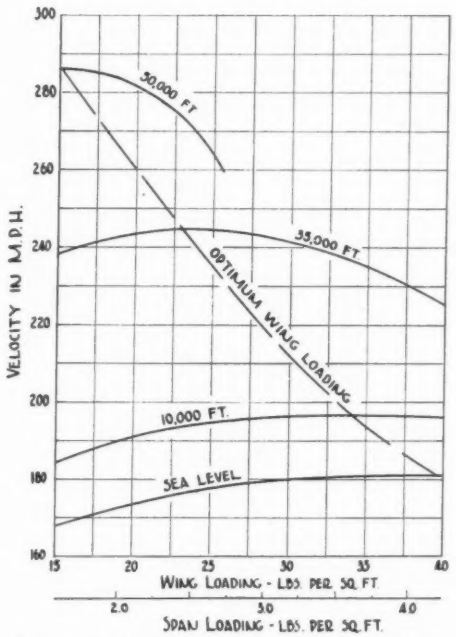

FIG. 4. Cruising speed *vs.* wing loading at various altitudes. Low-wing monoplane, aspect ratio 9.5, 20,000 lbs. gross weight; 12 lbs. per b.hp., cruising at 65 percent power.

make it profitable to go to higher wing loadings. Increased power has the general effect of increasing the best wing loading.

At 35,000 feet altitude, which is shown in Fig. 2, the optimum wing loadings are seen to be markedly less than those at 10,000 feet. The gradual shift of the best wing loading to higher values with increasing power and size of the ship is again evident. Also the greater penalty of employing too light a wing loading with the lower power loadings, and too high a wing loading with the higher power loadings is apparent. Seventy-five percent of the designs considered have a desirable wing loading of 25 lbs. per sq. ft. or less at this altitude. Over eight percent of the maximum obtainable cruising speed may be lost in a 20,000 lb. ship, with a power loading of 12 lbs. per b.hp., by increasing its wing loading from 25 lbs. per sq. ft. to 40 lbs. per sq. ft.

The peak in the velocity curve is even more pronounced at 50,000 ft., with a correspondingly greater need of designing for the specific cruising conditions as nearly as possible. Reference to Fig. 3 shows that the best wing loadings are still further reduced and a maximum of 25 lbs. per sq. ft. would include all designs considered. It will be noted that a good many of the ships cannot fly at this altitude with a wing loading considerably in excess of the optimum, without increasing the 65 percent power output. This is indicated by a cross (+) at the point of maximum wing loading possible.

A plot of the cruising speed *versus* wing loading from sea level to 50,000 ft. is made for a typical case in Fig. 4. The decrease of optimum wing loading with altitude is indicated by the faired line. The increased penalty of disregarding this value at the higher altitudes shows up clearly. The relatively small loss entailed by using a moderate wing loading instead of an excessively high optimum value at the lower altitudes is evident from the sea level and 10,000 ft. curves. It is well to bear in mind also that these moderate values of wing loading do not accentuate any of the take-off or climb problems.

The effect of aspect ratio is to alter the value of wing loading for a given span loading. Maintaining the span loading, the wing loading will increase or decrease in direct proportion to the change in aspect ratio. Hence the trends pointed out are perfectly general and any specific values for the wing loading used in the discussion may be scaled up or down if a conversion to an aspect ratio other than 9.5 is desired.

Besides the cruising speed the payload must be considered and this can best be done by evaluating an "efficiency factor" for each ship. This factor is the payload multiplied by the cruising speed and divided by the gross weight. The most efficient ship will have the highest payload-miles to its credit over a given time interval. The 20,000 lb. ship with a power loading of 12 lbs. per b.hp. was selected to investigate this parameter. The useful load for this ship was taken as 30 percent of the gross weight at a wing loading of 22 lbs. per sq. ft. Any decrease in wing weight, through an area reduction, was allowed to go directly into useful load. Such a procedure

optimistically assumes that the high lift device which allows the higher wing loadings does not cause any additional weight over that of a normal split flap installation at lower wing loadings. The unit wing weight is taken as proportional to $\sqrt{nW/c}$ where n is the high-angle-of-attack load factor, W is the gross weight, and c is the mean chord of the wing. This preceding formula was developed by B. C. Boulton.[5] A 1000 mile range is maintained and the variation in fuel required is calculated, using a specific fuel and oil consumption of 0.46 lb./b.hp./hr. Subtracting the weight of the fuel, oil, and crew from the useful load yields a value for the payload. It can be seen from Fig. 5 that under these conditions the efficiency factor might set a slightly higher value of the wing loading than that determined by the cruising speed.

Conclusion

With the preceding discussion in mind, the high-lift question assumes a new aspect. Knowing the gross weight necessary, wing aspect ratio possible, and the approximate power for the desired performance; an optimum span and wing loading for altitude cruising then may be determined by a consideration of the drag and power loadings. For the best cruising condition at altitudes ranging from 10,000 ft. to 50,000 ft., with normal gross weights and power loadings, this wing loading may well be in the range of those employed at present, utilizing a split flap. An additional evaluation should follow, balancing the speed decrease and possible structural weight decrease of a higher wing loading. Then the advantages of a high-lift, low-drag device upon take-off, climb, and ceiling may be considered and perhaps the installation made, if increased cost, maintenance, and weight are not excessive. The wing area being previously determined, a further decrease in landing speed below that required for minimum safety may then be a desirable by-product.

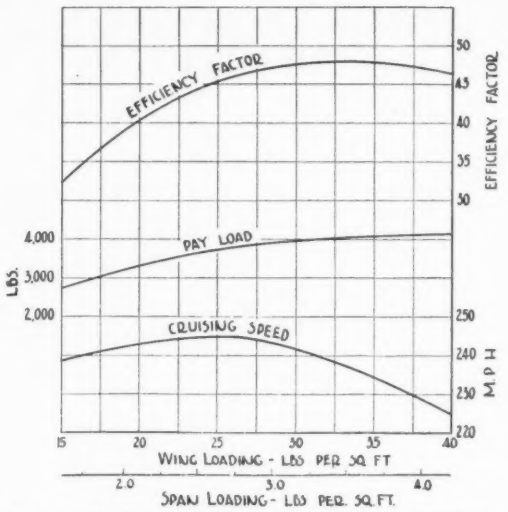

Fig. 5. Efficiency factor *vs.* wing loading at 35,000 ft. altitude. Low-wing monoplane, aspect ratio 9.5, 20,000 lbs. gross weight; 12 lbs. per b.hp., cruising at 65 percent power.

In conclusion, then, wing loading should be determined specifically for the predominant design condition. In high-altitude transport cruising operations with normal drag and power loadings there is a decidedly optimum value that does not greatly exceed those employed at present. Higher wing loadings may only be justified on the basis of decreased power and drag loading or a higher aspect ratio. This means, in turn, an increased overall cleanliness, decreased power plant weight, or a sacrifice of payload in favor of more power. There is no indication that extremely high wing loadings will be warranted for the class of ships considered.

[5] B. C. Boulton, *Aircraft Structures*, Journal of the Aeronautical Sciences, Vol. 4, No. 2, page 77, December, 1936.

Flight Test Research on a Small Bi-Motor Airplane

CLARENCE L. JOHNSON, *Lockheed Aircraft Corporation*

(Received March 23, 1937)

THIS discussion pertains to a group of miscellaneous flight tests, outside of the usual performance and stability tests, made on a Lockheed Model 12 bi-motor airplane. This airplane is a small, high-performance ship with a gross weight of 8400 lbs. and a top speed close to 230 m.p.h. The tests to be discussed, however, apply generally to our present day airplanes. The program of testing included among other things, the determination of:

(1) Lift and drag characteristics of the airplane.
(2) Effect of power on maximum lift coefficient with and without wing flaps extended.
(3) The drag of the streamlined tail wheel and strut.
(4) The effect of several servo-tab ratios in reducing the control forces.
(5) A one point measurement of the flow-speed ratio over the wing flap with power on and off.
(6) Airplane altimeter error due to position of pitot-static head.
(7) Factors affecting accuracy of engine fuel consumption tests.

The method of testing to obtain data on each of the above items will be taken up briefly and the results discussed.

Lift and Drag Characteristics

A complete series of wind-tunnel tests had been made on a one-seventh scale model of the airplane in the California Institute of Technology wind tunnel. The Reynolds Number of these tests was 1,600,000, or about one-tenth of the full scale value at high speed.

In order to make a comparison between the tunnel tests and full scale conditions, glide tests were made at eight values of indicated airspeed with the propeller r.p.m. such that little thrust was developed. The flight path was determined knowing the true airspeed and the tape-line rate of descent, which is equal to the rate of change of pressure divided by the average density. Correcting for the increment of propeller thrust using the latest N.A.C.A. propeller data, the drag coefficient at various lift coefficients may be determined. The gross weight of the airplane must be known accurately in this type of test and great care must be taken in avoiding vertical air currents.

The comparison of the wind-tunnel polar and the full scale data is shown on Fig. 1. For this particular airplane, it seems that any Reynolds Number correction on the minimum drag is cancelled out by the added drag of rivets, window recesses, ventilating scoops, and various other items of this type. It is interesting to note that there is an increase in the value of the airplane efficiency factor e, from the wind-tunnel tests, although not enough points were obtained at high lift coefficients to prove this conclusively.

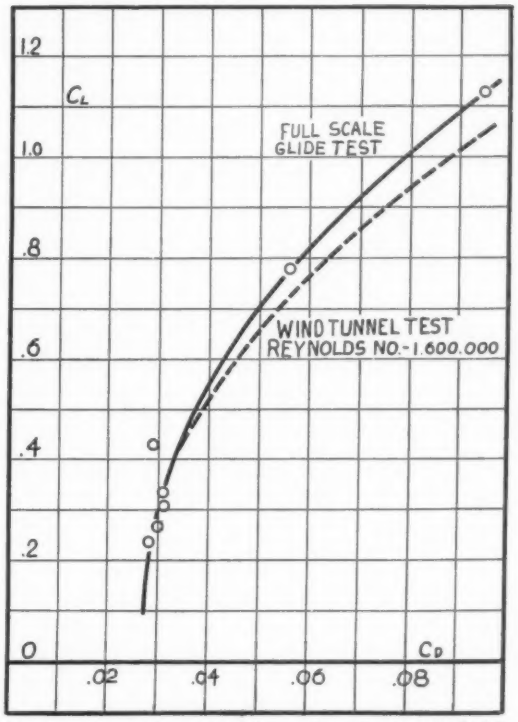

FIG. 1. Comparison of airplane polars, Lockheed Model 12.

Determination of Maximum Lift Coefficient

To determine this maximum lift coefficient, the airplane stalling speed was measured power off and on, with the wing flaps at 0° and 45°. A carefully calibrated trailing pitot-static bomb hung 35 ft. below the airplane to measure the speed. In the tests, the ship was carefully pulled up to the point where it fell out and the minimum air speed recorded under steady conditions. The airplane was equipped with constant r.p.m. propellers, so the engine power remained constant for the varying speeds for the power-on tests. With the wing flaps down and the engines on, the airplane reached very high angles of attack before stalling. While this angle was not measured, it seemed to the observer to

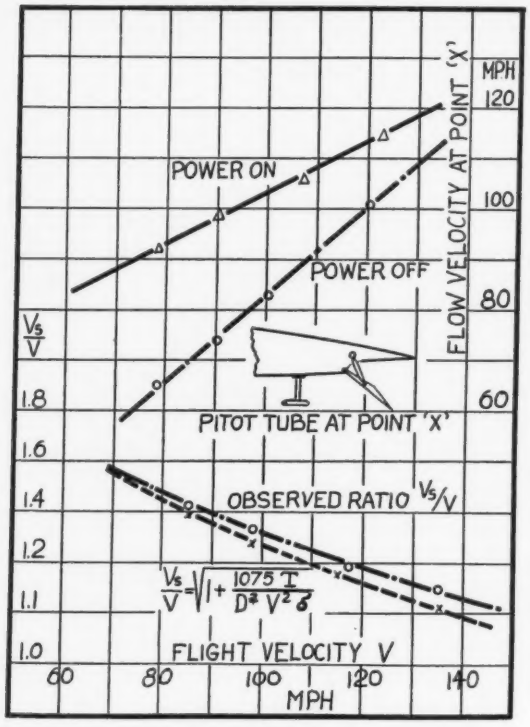

FIG. 2. Propeller slipstream effect on flow velocity over wing flap.

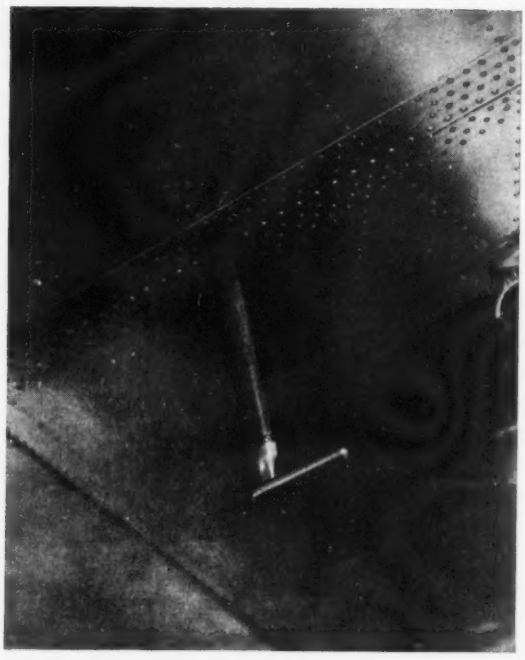

FIG. 3. Pitot-static tube located in front of wing flap for flow speed tests.

TABLE 1

B.hp./ Engine	Flap Angle	Aileron Droop	Engine R.p.m.	Maximum Lift-C_L
...	0°	0°	1000	1.44 to 1.50
260	0°	0°	2000	1.70
...	45°	10°	950	2.05 to 2.09
255	45°	10°	1950	3.09

be around 20°. This effect appeared to be substantiated by the very high lift coefficient obtained. The Model 12 has very large wing flaps, 80 percent of which lie in the propeller slipstream. A summary of the results obtained in the stall tests is given in Table 1.

EFFECT OF POWER ON FLOW SPEED OVER WING FLAPS

The high values of lift coefficient obtained with power on and flaps down in the above tests, pointed to the obvious conclusion that the propeller slipstream must greatly increase the flow speed over a very large percentage of the wing area on a bi-motor airplane like the Model 12. A few calculations quickly showed that the value of the maximum lift coefficient obtained (3.09) was not at all out of reason. To check the computations, it was decided to make a single point observation of the effect of the engine power or thrust on the speed of flow underneath the wing just ahead of the flap. A pitot-static tube was located 18 in. below the wing surface, 24 in. ahead of the wing flap hinge line at about the center of the flap span. The location was such that the maximum propeller slipstream effect would be measured.

Flight tests were made to obtain the slipstream velocity ratio which is defined as;

$$\frac{V_s}{V} = \frac{\text{Flow velocity at a given point with power on}}{\text{Flow velocity at the same point with power off}}$$

With the wing flaps set 45° and the propellers turning at the zero thrust r.p.m., glides were made at various indicated speeds from 70 to 140 m.p.h. and the flow speed as shown by the wing pitot-static tube recorded. The procedure was repeated at a constant engine power output of 370 b.hp./engine. The value of V_s/V obtained in the tests is plotted against the airplane indicated speed in Fig. 2. Very good accuracy could be obtained in this simple test.

If the slipstream velocity is computed using

$$\frac{V_s}{V} = \sqrt{1 + \frac{1075 \times \text{Thrust} \times \rho_0}{D^2 \times V^2 \times \rho}}$$

(E. P. Warner, Airplane Design, page 248. McGraw–Hill, 1927.)

where D is the propeller diameter in feet and V is the flight speed in ft. per sec., good agreement is obtained with the observed results. The flight test values are higher than the computed values. This is probably due to the fact that only a single point measurement was

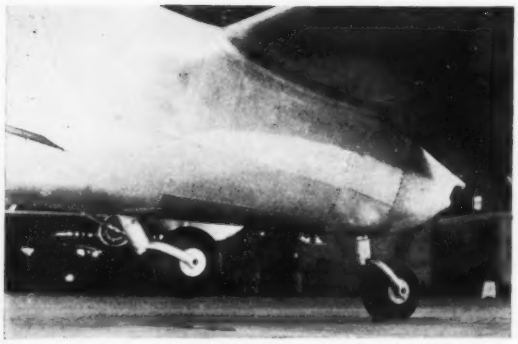

FIG. 4.

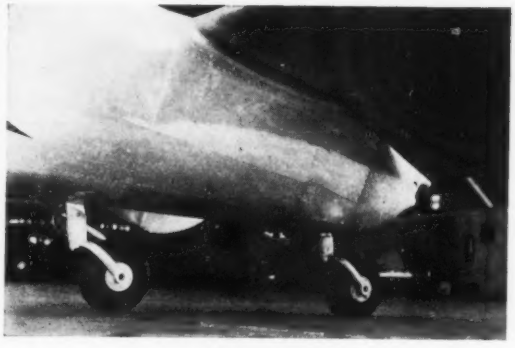

FIG. 5

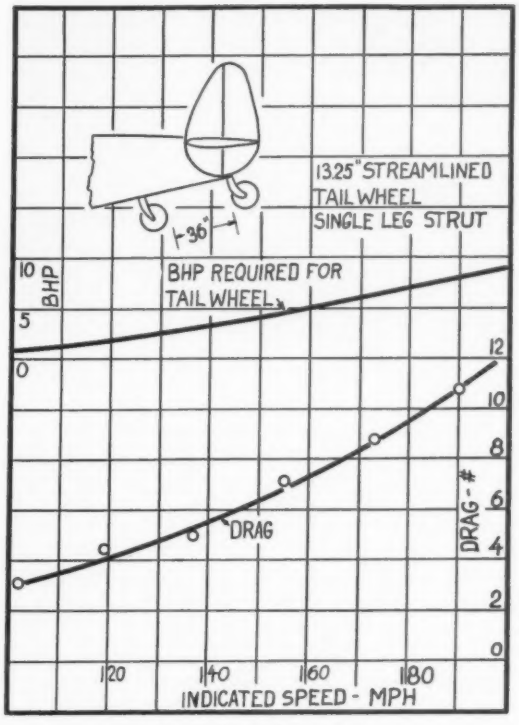

FIG. 6. Tail wheel-drag test.

obtained, and the average slipstream velocity ratio would be more nearly that given by the formula.

The effect of the propeller slipstream should be considered in determination of the wing-flap loads and in obtaining the balancing tail load for the flap conditions.

Making a few simple assumptions, the lift coefficient with flaps down will be estimated for the Model 12 for the conditions given in the stalling speed tests.

Total wing area	— 352 sq. ft.
Wing area in slipstream	— 156 sq. ft.
Thrust per engine	— 950 lbs. at stall
Slipstream velocity ratio	— 1.68
Lift coefficient of wing area with flap	— 2.1
Lift coefficient of wing area without flap (ailerons drooped 10°)	— 1.5

Assume that inclination of thrust axis gives lift which cancels tail-down load.

$$\text{Total lift} = 1.50\ (352 - 156)q + 2.1\ (156)\ 1.68^2\ q = \text{average } C_L\ (352)\ q$$

$$294q + 925q = 352C_{L\,max.}q$$

$$C_{L\,max.} = 3.45$$

The above computations, while very crude, nevertheless indicate that the value of $C_{L\,max.}$ obtained with flaps down and power on is quite reasonable.

TAIL WHEEL DRAG TESTS

The drag of the Model 12 streamlined tail wheel and single supporting strut was determined by actual measurement on a complete unit in flight. A dummy tail wheel was mounted 36 in. ahead of the airplane tail wheel in the manner shown in Figs. 4 and 5. The unit was attached to a carriage free to roll on ball bearings on tracks in the fuselage. The drag component of the tail wheel and strut could be measured in flight by attachment of a large scale to the carriage. The tare component of force due to inclination of the tracks in flight was obtained by measuring the track angle in flight with a protractor-level and applying the appropriate correction due to the weight of the tail-wheel unit. The drag was obtained for a number of different air-speeds. The engine power output was kept constant at cruising power, so the slipstream effect is included.

At a cruising speed of 200 m.p.h., the tail-wheel drag (with its strut) was 12 lbs. This is equivalent to a loss in speed of 1 m.p.h., a fuel consumption of .60 to .70 gals. per hr. at cruising altitude or a fuel cost of $.0005 (one twentieth cent) per mile.

REDUCTION OF CONTROL FORCES WITH SERVO TABS

The elevator of the airplane is fitted with powerful trailing edge trimming tabs of the conventional type but has no aerodynamic balance. Normally these tabs have no servo action (*i.e.*, they do not change their

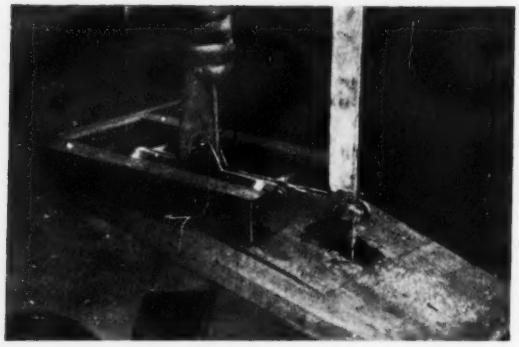

FIG. 7. Tail wheel-drag test unit showing carriage and tracks.

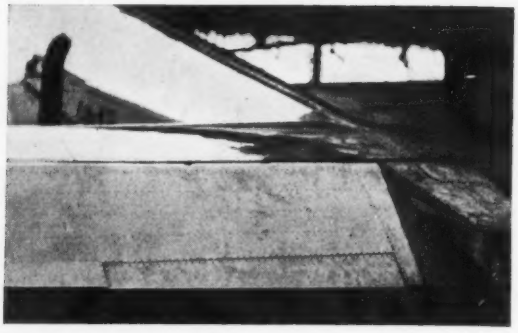

FIG. 9. Elevator with servo-tab used in tests.

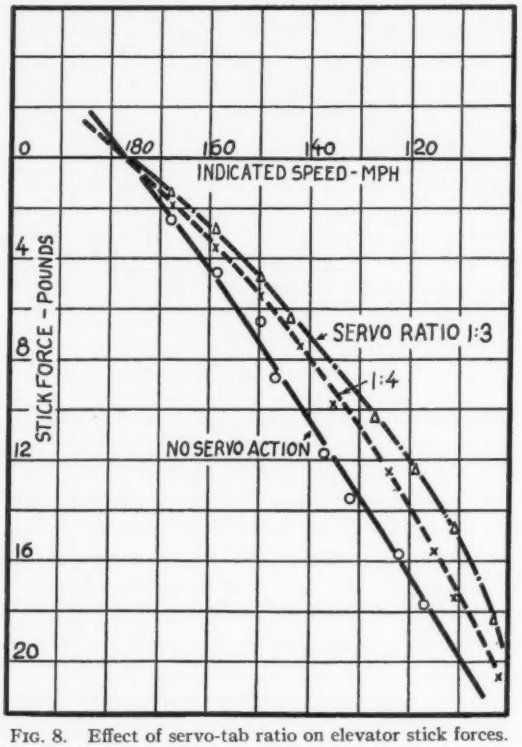

FIG. 8. Effect of servo-tab ratio on elevator stick forces.

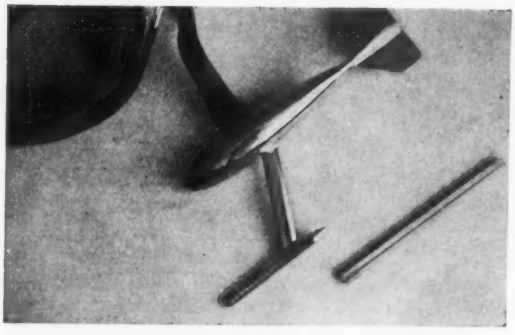

FIG. 10. Trailing pitot-static bomb used for airspeed and altimeter calibration.

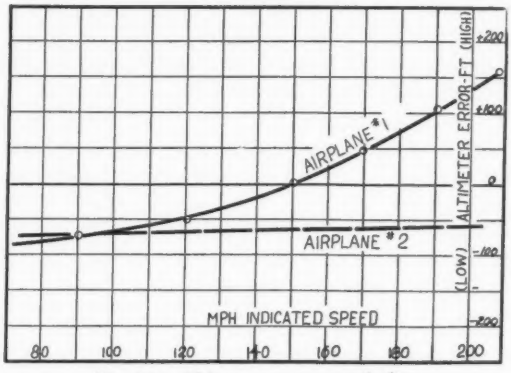

FIG. 11. Altimeter error *vs.* velocity.

angle to the elevator chord line when the elevator angle is changed). A number of flight tests were made to determine the effect of tab to elevator servo ratios of 1:3 and 1:4. In the first case, when the elevator angle changed 3°, the tab angle to the elevator chord line changed 1° in the servo direction, while in the second case, the corresponding angular changes were 4° to 1°. The elevator tabs have an aspect ratio of 5.1 and are 6.3 percent of the elevator area.

With a constant gross weight and center of gravity position, the airplane was trimmed for zero stick force at cruising power at 177 m.p.h. indicated speed. A large scale was attached to the control column for measuring forces. This was used to pull the ship up to various lower airspeeds and show the force required to balance the airplane in steady flight. The different servo ratios on the elevator tab reduced the stick force required for balance at any speed as shown in Fig. 8. An identical procedure was followed to get the data for each servo ratio. A considerable reduction in stick force was obtained with the 1:3 servo ratio with no tendency to overbalance at low elevator angles and with no tendency toward flutter. For a medium size airplane, it seems that stick forces can easily be held within the desired limits by the use of servo tabs only, without the use of aerodynamic balance.

AIRPLANE ALTIMETER ERROR

When the airplane altimeter and rate of climb indicator are connected to the static lead of the airplane

pitot-static tube, their readings are affected by the position error of the latter. Large errors in the airspeed readings indicated correspondingly large errors in the measurement of altitude and rate of climb for this case.

The method of determination of the altimeter error involves the use of the trailing pitot-static bomb as a source of true static pressure for calibration. With the bomb hanging a known distance below the airplane pitot-static tube, level flight runs are made at different airspeeds. The altitude shown by the airplane altimeter is compared to that given by a second altimeter connected to the static lead of the airspeed bomb. Curves showing typical altimeter error for two airplanes are shown in Fig. 11.

On many airplanes when a fairly sudden change is made in the flight path, pressure is built up at the static openings of the pitot-static tube so that the altimeter and rate of climb indicator which are connected to the static lead show a considerable rate of descent if the ship is nosed up or yawed. This is very undesirable during blind flying. It is possible to obtain a true static pressure measurement at some point inside of the cabin or even inside the wing, strange as this may seem. When such a point can be found (using the trailing bomb for calibration) it is better to obtain the static pressure for the altimeter and rate of climb indicator there than at the pitot-static tube. Care must be taken to find a point at which the pressure is not affected by the cabin ventilating system. In two airplanes tested, it was not difficult to find such a point.

Fuel Consumption Tests

During the course of the flight test, some engine fuel consumption tests were made. Very low specific fuel consumptions were obtained at cruising power when the usual engine power curves were used to determine the power. It should be pointed out however, that using the normal power curves when running on any mixture setting other than that for best power, results in considerable error in power determination. Assuming that the airplane is equipped with constant r.p.m. propellers, it is very easy to make flights at constant values of r.p.m., altitude, manifold pressure, and carburetor air temperature and obtain values of b.hp. varying as much as 10 percent for different mixture control settings. In other words, a great number of fuel consumption tests have been run and are being run by taking the power read from engine power curves based on maximum power mixture setting and dividing this power by the fuel consumed per hour at a much lower true power output. The resulting specific fuel consumptions obtained are actually optimistic by as much as 10 percent quite often. A true measurement of the specific fuel consumption can be made by a rather involved process involving propeller calibration in locked high pitch and careful measurement of the airplane speed at a constant power indication but with a complete range of mixture setting. The process is too long to be discussed here. Until engine torque meters are available for commercial use, it is best to speak of airplane fuel consumption on a basis of miles per gallon at a given airspeed and altitude rather than attempt to give values of specific fuel consumption derived in flight.

Institute Meeting at the National Air Races

"ENGINEERING for Speed" was the general subject of a meeting held by the Institute on September 4, at the Hotel Cleveland at Cleveland during the National Air Races. About one hundred attended and a lively discussion followed the reading of some of the papers.

T. P. Wright, Director of Engineering of the Curtiss-Wright Corporation, discussed the economics of speed. Parts of his paper follow:

From the economic standpoint it is necessary to find out "why" speed is of importance rather than "how" its achievement is possible. In this paper several reasons, purely economic in nature, are advanced in an attempt to prove that speed is of definite economic value. From the standpoint of history, it appears that in the progress of civilization speed of transportation has played a most important part and that now the advent of the airplane makes possible even greater speeds.

Economic Reasons for Air Races. Aerodynamic innovations which improve speed are usually first tried out in racing airplanes and two or three years later, the successful ones appear in commercial airplanes. It is in the improvement of the "breed" for the future that the true significance of air races is to be found.

To be of commercial value, speed must be obtained by aerodynamic means rather than through the mere piling up of horsepower. During the history of the airplane, speed records have increased at a uniform rate year by year, with speeds in commercial aviation following along.

Rail and Air Transport Comparisons. Comparisons between speed in rail and air transport show that the saving in time by the passenger for travelling distances of over one hundred miles or so is in the ratio of three and one-half to one. Considering the economic item, fare, it is found that from a time-cost efficiency basis the airplane is superior to rail travel by a ratio of almost two and one-half to one. Mention is made of an analysis which indicates that for distances of over nine hundred miles it always pays any company to send its travelling representatives by air rather than by rail if the salary of such representative is even at so low a figure as two thousand dollars a year.

Airplane and Air Transport Efficiency Factors. A distinction is made between airplane operating efficiency and air transport efficiency. The measure of efficiency for airplane operating is the cruising speed multiplied by the payload and divided by a factor representing operating cost. For air transport efficiency, however, where the time saving involved creates a demand on the part of the passenger for the means of transportation which saves the most time, it is necessary to multiply the original factor for operating efficiency by speed, thus making the transport efficiency factor equal to the speed squared multiplied by the payload and divided by the operating cost. Failure to recognize this dual role of speed has forced previous investigators to limit the economical air transport speed, such as was done by an English engineer in 1934 when he predicted limited airplane speeds from the economical standpoint of one hundred and thirty to one hundred and forty miles per hour.

Dollar Value of Speed Increase. From the standpoint of an engineer designing a large air transport, it has been shown that it is economically worth while to spend as much as three thousand dollars to gain one mile an hour in his experimental machine and that in the final production article, an increase in price of one thousand dollars is worth while to the operator if it means an extra mile an hour speed.

Conclusion. Great progress has been made in refining the airplane in the past eight years. In 1928 sixty-six percent of the total horsepower was wasted in overcoming unnecessary drag. This waste is now only twenty-five percent. And whereas their speeds were but sixty-five percent as fast as they should have been, present-day speeds are eighty-nine percent as fast, very little waste in drag remaining.

As direct proof of the various factors cited, reference is made to the growth of air transport throughout the past seven years wherin during a major business depression, a constant rate of increase in passenger miles travelled of thirty percent each year over the previous year has maintained. It is concluded definitely that speed is sound economically.

E. F. Zimmerman of the Shell Petroleum Corporation presented a paper on "Fuels for Speed."

Fuels used in several recent successful racing airplanes were discussed, with remarks on future possibilities. Since it is almost impossible to discuss fuels without bringing in the engines in which the fuels are burned, the principal makes of airplane engines used in recent races were described, beginning with the four-cylinder engines used in the 397 cubic inch class of racing plane, and ending with the 24-cylinder engine used by Italy in setting the present world speed record of 440.681 m.p.h. Specifications and photographs of each engine were given, with power curves where available. The high power output of racing airplane engines is due to improved design, metallurgical developments, and improvements in fuels and lubricants. As to fuels, early racing engines were operated on ethyl blended aviation gasoline of about 88 octane number, while present engines are operated on 100 octane fuel similar to the latest U. S. Army Air Corps fuel. When operated with this type fuel, the only limitation placed on engine output is the strength of the engine parts, as the danger of detonation is eliminated. Special fuels used in foreign aircraft engines were also described, with the observation that such fuels would probably be of little use in the present-day hot-running engines. At present, iso-octane is the principal constituent of 100 octane fuel, and the possibilities were explained of using toluene and di-iso-propyl ether in making such fuel.

E. T. Allen, test pilot and consulting engineer, read a paper on "Test Piloting." A summary of the paper follows:

Testing racers is like testing any kind of an airplane: a scientific, methodical, careful task for an engineer, not one for a daredevil. The daredevil has no place in modern testing. The man who covers up his incompetence in coping with the complexity of modern aircraft by referring to himself as a fatalistic test pilot will have his insurance rates increased. The engineering attitude of the test pilot is a most important factor in ensuring success and safety in a test.

Examination of the airplane prior to flight is the first task, an examination with an eye experienced in spotting causes of trouble before the trouble has a chance to materialize. Not only strength but rigidity as well—not only control but stability as well, should be assured before the airplane leaves the ground. The test pilot will go over the airplane minutely, imagining every possible combination of circumstances which might be difficult to meet with the capabilities of the airplane. This job is something like foreseeing several moves ahead in a chess game where every counter move may change the entire picture. The en-

gineering test pilot will not deliberately take any chances—but rather he will know in advance just what to do to meet each emergency. A rich experience in testing is here a great advantage because it enables the test pilot to foresee more possible causes of trouble than the inexperienced test pilot will foresee. Courage means little in this business; it is frequently used falsely to mean foolhardiness.

No flight is made without an exact plan and a tabulation of measurements to be made and test data to be obtained. Engine output and temperatures, airspeed and rate of climb, quantitative stability and controllability, landing and take-off data, are the routine measurements requiring skill and training to get accurately. Inaccurate data is worse than useless.

Does the design at these races improve the breed of airplanes? It is a moot question. Certainly the burden of proof is on the designers. Real improvement in airplane design, whether for military or commercial use means primarily efficient flight rather than merely speed. The old fashioned formula of maximum lift squared divided by minimum drag cubed has been forgotten at the races. To fly faster, safely, with less power, and with a larger useful load is the improvement really needed both for military and commercial ends. Racing design has been far surpassed by military and commercial design in real efficiency because the elements of real improvement are there kept clearly in view rather than, as with the racers, speed alone. If the rules at the races tended to develop really useful airplanes with safe landing speeds and carrying some payload they would be a greater aid to the aeronautical industry. If there was less emphasis upon the daredevil and more on engineering skill to produce speed safely, we would progress more surely and rapidly.

Robert Insley of the Pratt & Whitney Aircraft Division of the United Aircraft Corporation discussed the problems of engines in speed racing. Part of his paper follows:

Despite the fact that one purpose of this meeting presumably is to emphasize the importance of air racing to aircraft progress, it must become apparent sooner or later in the discussion of this subject that air racing in this country has influenced the development of aircraft engines to only a very limited extent. The reason for this unhappy condition is simply that the economics of air racing make no provision for such expensive luxuries as special racing engines or even for important alterations of existing engines, and consequently American racing engines with few exceptions have been standard commercial or military models. The information resulting from racing service, therefore, simply confirms or supplements that already obtained from other sources.

Even the fact that these engines are operated for the greater part of their useful lives at outputs well above normal service ratings is not of great significance, because modern development testing is such a drastic process that few engines reach racing status without having accomplished many hours of testing under conditions equally severe. For example, Pratt & Whitney Engines are rarely operated in races at outputs above their take-off ratings and the take-off rating is not established until the engine has proved itself capable of operating 100 hours at that output. Racing results therefore furnish simply supplementary test information.

So far as engines are concerned, the useful service performed by racing under present circumstances, seems to the author to be not the primary inspiration for engine improvements but the public demonstration of the results of such progress. The probable value of engine improvements is accurately determined in the laboratory before the improvements are made and the virtues of a new engine type are thoroughly examined in wind tunnels and elsewhere long before the type appears, but for dramatic and convincing proof no quantity of accurate theoretical analysis can equal the results of one race. The outcome of the Air Races a year ago caused more speculation about the value of reduced frontal area than could be produced by a dozen scholarly and thoroughly conclusive N.A.C.A. reports on the same subject, even though the race results quantitatively were completely valueless.

It is unfortunate that one must be so practical because in an ideal civilization peopled largely by air-minded philanthropists and governments intent upon speed without concern for military or commercial usefulness, air racing could be not only the royal sport that it is, but also an extremely useful proving ground for engines. Nothing even faintly resembling that happy state has ever occurred in this country. So far as the author recalls, there have been no engines developed in the United States strictly for racing purposes, with the possible exception of the Packard 24 cylinder "X" engine which suffered a regrettably early demise. But in countries where governments have contrived to give material expression to their enthusiasm for speed without the encumbrances of military specifications, the results have been extremely interesting. The Napier engine developed in England especially for Schneider Cup competition produced the lowest specific fuel consumption yet recorded, consistently below .30 lbs. per hp. hr., and occasionally as low as .285. The Rolls-Royce Schneider Cup engine produced well over one hp. per cu. in. of piston displacement and weighed $^2/_3$ lb. per hp., and the FIAT 24 cylinder tandem "Vee" engine developed the record output of 3100 hp. with the same specific weight. It is difficult to point out the direct influence of those accomplishments on engine development and from that point of view the soundness of the investment may be questioned, but it seems to the author that it is obvious that as the speed of service airplanes approach those of racing airplanes (as is now the case) the potential engineering value of racing should increase. It is not to be expected, of course, that engines developed strictly for racing purposes can be immediately useful for military or commercial service but it is not unreasonable to hope that a special, and if you like thoroughly impractical, engine built purely for speed might furnish information on performance limitations, on desirable shape and size, cowling design, cooling systems, and the like, which would be very useful in the development of service types.

The author freely confesses that his remarks from here on were inspired rather by technical curiosity than by business sense but those who have similar curiosity may be interested in considering briefly some of the possible requirements of an engine intended strictly for the purpose of transporting one human being through the atmosphere at the highest possible speed.

Even the most rabid round-engine enthusiast will not cavil at the statement that an engine for strictly racing purposes must offer the maximum power with the minimum frontal area. Assuming, therefore, that there is to be a single engine in a fuselage, the limiting size of the engine is determined by the projected area of the pilot in his most compact useful position, and the engine naturally will be a long and slender affair. It would occupy all of the fuselage forward of the pilot, and since it presumably would interfere with continuous wing spars it might profitably be provided with fittings for attachment of the wing structure. In that case the airplane would be in effect a power plant with wings and tail group attached to it.

Assuming that it would be possible to crowd 2000 to 2500 short-time horsepower into that space and assuming that the wings would be of negligible area the torque reaction from a single propeller would undoubtedly be disastrous, and our racing engine therefore would include a reduction gear to drive two counter-rotating propellers.

The cooling system would be a problem. The engine would be liquid cooled for minimum drag and it would be difficult to find sufficient available surface on the whole airplane for "skin" radiators. However, for short speed dashes it seems likely that a ducted system built into the structure could be used and the whole system closed and a portion of the coolant allowed to boil

off for the duration of the actual speed flying. For flights of longer duration surface radiators probably would have to be supplemented by small ducted radiators built into the structure.

The engine itself would consist of a large number of small cylinders delivering in excess of 1 1/4 hp. per cu. in. of piston displacement and would weigh dry somewhat less than one lb. per per hp. It would include only such accessories as are absolutely necessary and in normal operation would require such high manifold pressure that there would be little supercharger capacity left over for altitude performance. Obviously it would not be an engine applicable directly to military or commercial service and the author hastens to add that no engine manufacturer is likely to build such an engine on speculation.

Richard W. Palmer of the Hughes Aircraft Company spoke on "Design for Speed" of which the following is an abstract:

A very important point in the design of a pylon racing plane, which often has been overlooked, is the aspect ratio (proportion of span to mean chord) of the wing. A racing plane of 400 hp., 2000 lbs. weight, and 80 sq.ft. wing area could be built to have a speed of 300 m.p.h. in a straight line. But in a right-angled pylon turn at the customary steep bank, this plane would lose about 40 m.p.h. of its speed if it had an aspect ratio of three. With an aspect ratio of five, the loss would be about 20 m.p.h.; with seven, only 10 to 15 m.p.h. Considering losses such as these, the aspect ratio of pylon racing planes should be high, say in the the neighborhood of six.

Frank W. Caldwell of the Hamilton Standard Propellers Division of the United Aircraft Corporation spoke extemporaneously on the use of propellers for increased speeds. He said that multi-bladed propellers could probably take up to 3000 hp. by the use of four and six blades with little loss of efficiency but a marked increase in weight. Co-axial propellers rotating in opposite directions also showed relatively little loss in efficiency but added considerable in complication in gearing and shafting.

Among those present were Air Commodore T. E. B. Howe, British Air Attaché; Val Cronstedt and A. A. Andrake of the Lycoming Division of the Aviation Manufacturing Corporation; John M. Tyler; Paul E. Hovgaard, Robert A. Darby, O. L. Woodson, and George C. Rough of the Curtiss Aeroplane and Motor Company; M. F. Vanik, P. H. Schneck, Jack L. Rohm, Bruce Richardson, and Philip A. Essi of the Curtiss-Wright Corporation; George E. Read of the Calumet Refining Company; A. Handler and Frank Jardine of the Aluminum Company of America; H. M. McFadgen, Jacobs Aircraft Engine Co.; Clayton J. Brukner, Waco Aircraft Co.; Deed Levy and C. C. Sherwood of Stearman Aircraft Co.; A. T. Colwell and M. Thoren, Thompson Products; Byron Masterson, Hughes Aircraft Co.; H. V. Putten and R. F. Yee, University of Michigan; J. W. Welborn, Spartan Aircraft Company; Major R. W. Schroeder, United Airlines; Grant MacDonald, Edo Floats, Canada; Dr. T. H. Troller, Guggenheim Airship Institute; F. B. Stulen and L. L. Garber, Pittsburgh Screw and Bolt Corporation; H. C. Hunter, Gulf Research and Development Co.; R. M. Faris, F. A. Faller and A. J. Stuart, Shell Petroleum Corporation; H. R. Liebert, Goodyear Zeppelin Corporation; M. N. Gough, N.A.C.A.; Earl D. Osborn, Edo Aircraft; B. W. Ainsworth and James B. Taylor, Taylor-Ainsworth; Herbert Thaden, U. S. Steel Corporation; Ralph Upson; S. Paul Johnston and Charles F. McReynolds, "Aviation Magazine"; Frank Miller, Western Flying; Burnham Adams, Wright Aeronautical Corporation; Frank D. Sinclair, A. Kartreh and Hart Miller, Seversky Aircraft Corporation; Roland Rohlfs; William Gould, Pratt & Whitney Aircraft Division United Aircraft Corporation; Raymond B. Quick, U. S. Aviation Underwriters; Rex B. Beisel, Chance Vought Aircraft; and John F. Victory, N.A.C.A.

Institute Notes

Meeting of Pacific Coast Section

Approximately one hundred members and sixty guests of the Institute attended a supper and technical meeting of the Pacific Coast Section on Friday evening, August 27, at the California Institute of Technology in Pasadena.

Dr. Irving P. Krick of the California Institute of Technology spoke on "Recent Advances in Aeronautical Meteorology," and showed slides and motion pictures by way of illustration. Of particular interest were his discussions of the radio meteorograph and of progress in forecasting the time of fog dissipation.

Schuyler Kleinhans of the Douglas Aircraft Company gave the results of a statistical study of "Landing Speed, Take-Off Distance and Time, and Safety, *versus* Size and Weight of Airplanes and Flying Boats," in which the trend in design as size increased was graphically illustrated.

Dr. Norton B. Moore, chairman of the executive committee of the Pacific Coast Section announced the following tentative program which has been drawn up for the coming twelve months:

A meeting in Los Angeles early in November, dealing, tentatively, with icing problems.

A meeting in San Francisco, the latter part of November.

The Wright Brothers Lecture and banquet, to be held at the California Institute of Technology, probably December 21, and to be delivered by Professor B. Melvill Jones of Cambridge University, on "Boundary Layer Experiments in Flight."

A meeting in the vicinity of Los Angeles early in February (*i.e.*, about two weeks after the annual meeting in New York) at which material presented in the East will be discussed.

A meeting the latter part of March in Los Angeles, in connection with the American Society of Metals Congress, at which the chief subject will be the use of metals in aircraft.

A first annual summer national meeting, to be held on the Pacific Coast, in the vicinity of Los Angeles, the latter part of June. This is expected to be at least a two-day meeting, similar in scope to the annual meeting in New York.

Inspection of America's Cup Yachts

Fifteen members of the Institute were guests of T. O. M. Sopwith at Newport on July 23.

The party was also the guest of Harold S. Vanderbilt on a visit to the yacht *Ranger*. Mr. Vanderbilt explained the innovations that were incorporated in the construction of this year's America's Cup defender and stressed the great advantages that he believed had been obtained by tests made in the towing tank at the Stevens Institute of Technology. Mr. Sopwith then took the group to the *Endeavour II* and permitted a complete inspection of the challenger. Later he entertained his fellow members on his motor yacht *Philante*.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps.

Aerodynamics

Calculation of the Effect of Compressibility of the Air on the Size, Direction and Moment of the Lift of an Airplane Wing. P. A. Walther. Some formulas for the calculation of lift and moment are quoted from Russian reports. Abstract in Italian. L'Aerotecnica, May, 1937, pages 460–461, 9 equations.

Experimental Research on the Aerodynamic Effects on the Oscillating Wing. P. Cicala. Results of a series of tests developed at the Aerodynamic Laboratory at Turin for determination of the moments due to oscillation of a wing profile about a focal point, and of the variations of lift produced by the translational oscillation of the profile. L'Aerotecnica, May, 1937, pages 405–414, 6 illus., 2 tables, 4 equations.

The Langley Field Conference. A. Klemin. Professor Klemin's account of the Annual Meeting at the N.A.C.A. with comments on the principal experiments shown there, including work on catapults for transport airplanes. Aircraft Engineering, July, 1937, pages 191–193, 1 illus.

Theory of the Wing Submerged in Water and the Gliding Surface. F. Weinig. Wing theory results applied to the wing under water, and drag of the free surface of gliding surfaces. Discussion covers: drag conditions with gravity neglected; two-dimensional problem of the submerged wing and gliding surface; submerged wing of finite span according to the theory of the lifting vortex curve and induced drag; gliding surface as the limiting case of the submerged wing and the necessity for substituting a more general term for circulation; limitation of lift by cavitation; and wave resistance in general under effect of gravity. DVL report. Luftfahrtforschung, June 20 1937 pages 314–324, 28 illus., many equations.

Wind Tunnel of the Institute of Aeronautical Construction of R. Politecnico at Milan. S. Bassi. Characteristics of wind tunnel with simple return and free jet, and description of the three-component balance. L'Aerotecnica, April, 1937, pages 317–327, 11 illus., 2 tables.

Aircraft Design

Coronation Comment. Observations on the technical review of aircraft and engines given by Thurston James in the Coronation Number of the magazine. Advantages of the biplane over the monoplane, Villiers Maya engine, sleeve valves, and radial engines are discussed briefly, and comments are made on opinions of an American designer regarding limitations to cylinder number in the multi-row radial engine. Aeroplane, June 23, 1937, page 768.

Fleet Air Arm Aircraft. H. J. C. Harper. Special problems that face the designer of military aircraft for aircraft-carrier operation, methods of easing the pilot's task, and details of deck-flying routing are discussed in deta Flight, June 24, 1937, pages 632a–632d, 633, 6 illus.

Letters to the Editor. Effect of slipstream on longitudinal stability is discussed by R. S. Stafford with criticisms of a recent article by J. H. Crowe. The latter's reply is included. Additional information on gust loads is given by R. V. Rhode who refers to work at the N.A.C.A. Aircraft Engineering, July, 1937, page 194.

Technical Notes. Pouit low-lift wing flaps for landing. Ordinary ailerons are placed by slot ailerons of the Frise type; that is to say they are articulated at the center of pressure in such a way that their mobility will be maximum. Brief note. Les Ailes, July 1, 1937, page 6.

Trailing-Edge Flaps. S. B. Gates. Purpose of flaps, and how far they achieve it. General review covering need for flaps, use in landing and take-off, properties of trailing-edge flaps, present state of flap design, flap operation, longitudinal trim obtained, effects at stall, future of flaps, and the economical step to the Fowler flap. Aircraft Engineering, July, 1937, pages 183–186, 3 illus.

How Many Engines? A. E. Lombard, Jr. Estimated characteristics of three proposed pressure-cabin transport airplanes suitable for cruising at 20,000 ft., their estimated direct operating costs, and characteristics of 16 engines are presented. The performance, weight, and economy of each of these airplanes are considered when they are powered with two or four engines. Discussions of the number of engines required for transport airplanes operating under the Department of Commerce, and safety assured by the four-engined airplane requiring two engines for flight, or the two-engined airplane requiring one. Aviation, July, 1937, pages 30–31, 63, 64, 67, 68, 6 illus., 2 tables, 2 equations.

Stress Analysis and Structures

An Application of the Method of Fixed Points. L. Kirste. Method of solving the problem of bending-torsion, given in the January issue of L'Aéronautique, is applied to the calculation of a beam acted upon by transverse and longitudinal forces. The method shows whether or not a stable solution is possible with the given values, and takes into account variation of the values along the span and effect of some modifications. La Technique Aéronautique, No. 143, 1937, pages 38–44, 7 illus., many equations.

Constants for Channel and Other Sections. W. Wilson. Quick method for obtaining the geometrical constants for channels, Z-sections, H-sections, angles, T-sections, and V-sections of constant thickness. Flight, Aircraft Engr. Sup., June 17, 1937, pages 35–39, 17 illus., 2 tables, many equations.

The Flexural Line. E. W. H. Thompson. Amplification of the method of interpolating a flexural line between the limiting flexural lines of taper wing loading and uniform loading when the "R" line is linear. Reference is made to previous article by H. N. Horne entitled "The Stressing of Monoplane Wings." Flight, Aircraft Engr. Sup., June 17, 1937, pages 39–40, 1 illus., 9 equations.

Normal Torsional Stresses of Structures with Rigid Bulkheads. P. Cicala. Wing structure having two spars with ribs but without stressed covering, and systems analogous to spar-rib structures are considered. Torsion of a box with stressed covering at the edge, or subject to a diagonal field of tension, the torsion of a fuselage structure, and the flexure of beams with thin bases are analyzed. L'Aerotecnica, February, 1937, pages 80–119, 15 illus., 5 tables, 27 equations.

Official Methods Used in U. S. S. R. for Calculating the Strength of Materials for Airplanes. M. Précoul. Official Russian methods for calculating the strength of military and commercial airplanes are described with examples, and are compared with French regulations of 1925 and directions of the DVL. This issue covers categories of military and civil airplanes and calculation of the wing in flight at maximum lift, at small angles of incidence, and in a nose dive, as well as in inverted flight. To be continued. L'Aérophile, May, 1937, pages 106–110, 6 illus., 7 tables, many equations.

Torsion of a Wing Having Two Rolled Spars with Restraints. G. Salvadori. Wing structure in which two rolled spars are joined by a double diagonal restraint. Some simplified hypotheses confirmed by practice are drawn, and formulas are developed by finding the dimensions of the spar web and stretching of the two restraints. Formulas are given for verification of the angle of torsion and the extension for each. L'Aerotecnica, April, 1937, pages, 328–332, 4 illus., 10 equations.

Official Russian Methods for Calculating the Strength of Airplanes. M. Précoul. Russian regulations regarding strength in landing in a vertical drop, simple distribution of load, load distribution along the span, distribution of load by chord of a multiplane wing unit, slotted wings, calculation of ribs, and ailerons. Continued. L'Aérophile, June, 1937, pages 132–136, 6 illus., many equations.

The Solution of Buckling Problems by an Approximate Method. A. N. Procter. Least-energy methods are adapted to solutions for a column with hinged ends, column with fixed ends, column with varying load or cross section, eccentrically-loaded column, and column with lateral load. To be continued. Engineering, July 16, 1937, pages 62–64, 5 illus., 12 equations.

Testing Shock-Absorbing Struts. W. D. Douglas. Dynamic tests of axially-loaded undercarriage struts at the Royal Aircraft Establishment. Falling-weight type of testing machine developed; means for obtaining continuous reaction-time records, indication of maximum reaction sustained by strut during impact, and permanent record of closure of strut or tire at any instant during impact; camera for photographic recording; means for representing a landing in which aircraft is completely airborne during impact; test procedure; and results. Long article. Aircraft Engineering, July, 1937, pages 177–182, 15 illus., 3 tables.

Aircraft Performance

Determination of Airplane Stability. M. Watter. Flight tests to determine factors entering into the problem of balance, stability, efficiency of stabilizing, and control surfaces, as well as airflow behavior near the tail including slipstream effect. Flight test data to be obtained, and formulas for the analysis of data on elevator angles versus speed required for trim. Data published by permission of Glenn L. Martin Company. Aero Digest, August, 1937, pages 22 and 64, 1 illus., 1 table, many equations.

Nomographs for the Calculation of Distance and Time of Take-Off of Airplanes. G. Foa. Nomographs given cover take-off from hard and smooth ground or runways, from a good field with hard grassy ground, from a medium field with short grass, and from a medium field with long grass or from loose ground. Principal methods of making these calculations, and use of the nomographs. L'Aerotecnica, January, 1937, pages 33–38, 1 illus., 6 equations, 5 graphs on suppl. plates.

Rate of Climb and Descent Indicators. H. Danielzig. Determination of the rate of climb and descent of an airplane by the photographic method, by variometer measurements, and by the indirect evaluation of vertical speed from the curve of the recording altimeter. The DVL double recorder and results of tests in the Albatros L-75 airplane are discussed in detail. DVL report. Luftwissen, May, 1937, pages 153–157, 6 illus., 7 equations.

Aircraft Units

An Ingenious Remote Control. New Exactor mechanical control for smaller aircraft makes use of a single wire automatically kept at constant tension and capable of transmitting push-pull loads. In event of a wire being broken (e.g., by gunfire) the control will travel to the predetermined position. Flight, June 17, 1937, page 602, 2 illus.

No More Landing Gears? Landing and take-off of airplanes without nding gear has been accomplished successfully be means of a movable ack. Brief reference. Scientific American, July, 1937, page 55.

The Origin of Flaps. Development of flaps by C. F. R. Fairey and the Fairey Aviation Company is traced, and reference made to the split flap fitted to Westland aircraft. Aeroplane, June 16, 1937, page 733, 7 illus.

Retractable Alighting Gear. General G. A. A. Fiore. Fourteen different types of retractable alighting gear with longitudinal movement, and ten with transverse movement are described and illustrated. Types only with no mention of designers or manufacturers. L'Aerotecnica, January, 1937, pages 3–32, 24 illus.

Aircraft Vibration Measurement

Flutter of Aircraft Wings. H. G. Kuessner. Testing apparatus and results obtained by H. L. Studer and J. Ackeret in 1933 and 1936 are considered and practical importance of the results discussed. V. D. I., June 5, 1937, pages 673–674, 3 illus.

Vibration Measurement. Mechanically-operated frequency meter developed at New York University to determine the material frequencies of parts of aircraft structures by means of different types of vibrators, essentially unbalanced weights, which are excited from 200 to 10,000 cycles per minute. Natural frequencies of the structure are obtained on the ground in the unloaded or unstressed condition. Few details. Aero Digest, July, 1937, page 73.

Aircraft

Comments on the Fifteenth Paris Aeronautical Show. Capt. F. Fassio. Descriptions, characteristics, performance, and, in some cases, armament and comparisons of the following airplanes: Mureaux 190 and Morane 405 pursuits, Mureaux 200 A.3 three-place reconnaissance, Bréguet 462 bomber,

Koolhoven F.K. 55, Polish PZL P-24 single-seater pursuit, Loire 250, Hanroit 220 three-place combat, Fokker G-1, Amiot 341, Bloch 131, Russian 2KB-19, and Potez 63. Engines discussed and illustrated include: the new Gnôme-Rhône L. 18, Bristol Hercules, Wright Cyclone, Salmson 12 VARS, farman 12 CRS, Lorraine 12D horizontally-opposed, Gnôme-Rhône M. 14, Rolls Royce Merlin, and the Walter Sagitta. L'Aerotecnica, May, 1937, pages 379–404, 50 illus., 1 table.

Foreign Airplanes Exhibited at the Paris Show. P. Léglise. Fokker G. 1 "Le Faucheur" two-place two-engined attack, reconnaissance and light bomber, Koolhoven F.K. 55 single-seater pursuit, and the long-range A.N.T. 25 airplane are described in great detail. Ten pages devoted to the Fokker describes its construction, armament, equipment, characteristics, performance, and loading. Many drawings and photographs of these airplanes are included.

This article is followed by many drawings of the following aircraft: P.Z.L. P. 24; A.N.T. 35; Z.K.B. 19; Russian Stakhanovetz glider; Benes-Mraz B.E. 500; Prage Baby; Bata-Zlin; Praga 114 E; French motorized observation balloons Aérazur and Zodiac; and the S.C.A.L. F.B. 30, and S.F.A.N. Kellner-Bérchereau French sport planes. L'Aéronautique, April, 1937, pages 63–72, 73–78 and 79–85, 70 illus.

1937 Touring Airplanes. The two-seater Stani automobile-airplane, and the Kellner-Bechereau EI single-seater, as well as the roadable autogiro and the Waterman W-5 Arrowbile are described. L'Aérophile, May, 1937, pages 103–105, 14 illus.

The XV Paris Aeronautical Exhibition. Interesting features of military and commercial aircraft exhibited. Tables give specifications, and in some cases performance, of bombers, light bombers, combat, and pursuit airplanes exhibited. Drawings are taken from "Flight," "Aeroplane," and "L'Aéronautique." Long article. L'Aerotecnica, February, 1937, pages 153–175, 40 illus., 3 tables.

Austria

Hirtenberg HV-15 High-Speed Transport. Austrian twin-engined transport monoplane having a maximum speed of 235 km./hour when powered by two Siemens 1H 14-A engines, and 290–310 km./hour with two Walter Castor II 340-hp. engines. Range is 900 km. Brief description, dimensions, performance. L'Aerotecnica, February, 1937, pages 180–181, 2 illus., 1 table.

Belgium

Airplanes. Renard R-35 trimotored 20-passenger stratosphere transport when powered by three 700-hp. engines has a maximum speed of 360 km./hr. at 5000 meters, and, when powered by three K-14 950-hp. engines, a maximum speed of 435 km./hr. at 5000 meters. Characteristics, performance, and details and photograph of pressure cabin given. Renard R-36 single-seater pursuit (910-hp. Hispano-Suiza 12Y-21 "moteur canon," maximum speed 505 km./hr. at 4000 meters) may be changed to a two-place combat airplane. Armament, characteristics, performance. Few details and photographs of the following: Belgian Fairey Battle (Rolls-Royce Merlin 1050-hp. engine, maximum speed 450 km./hr. with 700 kg. of bombs); W-4 Oplinter light touring plane; Belgian Peetermans bimotored transport; and S.A.B.C.A. S-30 light two-seater touring airplane. L'Aérophile, June, 1937, pages 123–124, 7 illus.

France

Five Airplanes in the Duralumin Competition. Design and construction of five light airplanes entered in the contest of the Société du Duralumin are described in detail with characteristics and performances. They are the Alliet-Lariviere constructed by Bloch, the Kellner-Béchereau with an unusual wing, the Roussel "Solo" designed especially for good visibility, the Daspect Moto airplane, constructed by Gourdou, and the two-seater Jarrion. Long descriptions. Les Ailes, June 3, 1937, pages 8–9, 8 illus.

New Airplanes in Test. Gourdou 32-C. 1 dive bomber (Hispano-Suiza 12-Xcrs engine), LeO H-46 bomber with two floats (two Gnôme-Rhône K-14 870-hp. engines), Romano R-120 bomber developed from the triplace R-110, Romano R-130 light single-seater pursuit which, powered by a Renault 450-hp. engine, should attain 480 km./hour at 4000 meters, LeO H-45 night bomber, a light Bloch defense plane equipped with two Gipsy engines, Amiot 150-B.E. 6-passenger flying boat for combat, exploration, bombardment, or torpedoing (two Gnôme-Rhône K-14 engines), Bloch 131, and Morane-Saulnier 405 C-1 No. 2. Very brief notes. Les Ailes, June 3, 1937, page 7.

The Potez 63 Three-Seater Light Defense Plane. A. Frachet. All-metal three-seater two-engined monoplane with interchangeable equipment for carrying out missions of pursuit, bombardment, and reconnaissance. Equipped with two Hispano-Suiza 14-Ab 670-hp. engines the plane has a maximum speed of 460 km./hour at an altitude of 4000 m. Long description, characteristics, and performance when fitted as pursuit, bomber, and reconnaissance airplane, respectively. Les Ailes, June 3, 1937, page 6, 2 illus., 1 table.

Air-Wibault Four-Motored Transport. Air-Wibault 25-ton transport to be powered by four engines giving a total of 5400 hp. and to transport 72 passengers over 500 km. has an estimated cruising speed of 330 km./hr. Few details. The Breguet 760, also being developed, will be powered by four Gnôme Rhône 14 N.O. engines giving a total of 4400 hp. and will transport 56 passengers and 1720 kg. of freight. Maximum estimated speed is 380 km./hr. Characteristics and estimated performance only, no illustrations. L'Aérophile, June, 1937, page 128, 4 illus.

Airplanes in Test. Caudron-Renault C-690 pursuit, Morane Saulnier 430 two-place trainer, Caudron-Renault C-670 light reprisal and reconnaissance, and Caudron-Renault 710 single-seater pursuit airplanes. Brief references to these military airplanes undergoing tests. Les Ailes, July 1, 1937, page 13.

Amiot 370 Bimotored Racing Airplane. The Amiot 370 powered by two Hispano-Suiza 12-Yirs 860-hp. engines has a maximum speed of 475 km./hr. and range of 7000 km. Construction, characteristics, performance, and drawings illustrating equipment and location of the fuel tanks in wings and fuselage. L'Aérophile, June, 1937, page 127, 8 illus.

Foreign News in Brief. Seventeen-ton 220-m.p.h. Liore et Olivier flying boat Air France plans to operate across the Atlantic. Photograph only. Reference is made to 18 new seaplanes having a speed of 200 m.p.h. with a 1-ton load and range of 3000 miles and ordered by Air France for experimental flights across the South Atlantic. Aero Digest, August, 1937, pages 80, 78, 1 illus.

Technical Notes. A Bréguet-Wibault 360-6 has been equipped with a Clerget 14-cylinder 34-liter 500-hp. heavy-oil engine and flown at Villacoublay, and a Bloch 200 has been equipped with two of these engines. Brief reference. Les Ailes, July 1, 1937, page 7.

Germany

Air and Water. A helicopter is said to have broken all the world records at Breman. It reached a height of 2500 meters, remained in the air for 1 hour 20 min. 49 sec., attained a speed of 122 km./hr. over 20 km., and was flown in a straight line 16.4 km. and in return 80 km. Brief reference. Engineer, July 9, 1937, page 43.

Airplanes. Gotha G.O.-146 four-place transport (two Hirth H.M. 508-E 200-hp. engines, maximum speed 315 km./hr.) and the Junkers 83 two-engined transport of large capacity (two Junkers Jumo 600-hp. heavy-oil engines, maximum speed 365 km./hr.). Characteristics and performance only. L'Aérophile, June, 1937, page 125, 2 illus.

Foreign News in Brief. Twin-engined Halle Fh-104 high-speed transport powered by two 240-hp. Hirth Vee engines. Photograph only. Aero Digest, August, 1937, page 79, 1 illus.

Arado Ar 77. Training or sport plane powered by two Argus as 10C air-cooled inverted 240-hp. engines has a maximum speed of 243 km./hour. Details of design, characteristics, and performance. Luftwissen, May, 1937, page 159, 1 illus., 1 table.

The German Henschel Single-Seater. Henschel single-seater combat biplane powered by a B.M.W.132 550-hp. engine. Photograph and very few details. L'Aérophile, May, 1937, page 98, 1 illus.

Hamburg Ha1 39. Catapultable long-distance postal flying boat powered by four Junkers Jumo 205-C 600-hp. heavy oil engines has a maximum speed of 300 km./hour and range of 500 km. Details of design, characteristics, and performance. Luftwissen, May, 1937, pages 159–160, 1 illus., 1 table.

A New Development of the Focke-Wulf Fw 58 "Weihe." Focke-Wulf Fw 58-B for training in night and instrument flying and in machine-gun firing and bombing. Few details. L'Aerotecnica, February, 1937, pages 181–182, 2 illus.

Great Britain

Airplanes at the Display. T. James. Eight new airplanes to be shown at New Type Park during the R.A.F. Display include: Airspeed Oxford Trainer and Queen Wasp; Blackburn dive bomber; De Havilland Albatross transatlantic plane and Don trainer; Fairey P.4/34; Gloucester F. 5/34 single-seater fighter; and Hawker P.4/34 Henley. References to the above airplanes and a few details, performance and engines of the following airplanes taking part in the Display: Bristol Blenheim; Handley-Page Harrow; Armstrong-Whitworth Whitley; Vickers Wellesley, Vildebeestes and Virginias; Avro Ansons; Fairey Battle and Gordon; Gloster Gladiators and Gauntlets; Hawker Hectors, Hinds, Demons and Furies; Boulton-Paul Overstrand; and General Aircraft Monospar. The Blackburn dive bomber (Bristol Mercury 880-hp. engine, folding wings), Gloster F.5/34, Don Crew trainer, Hawker Hind, Magister trainer, and Airspeed Oxford are illustrated. Aeroplane, June 23, 1937, pages 751–754, 747, 11 illus.

The Bristol Blenheim. Three-seat high-speed medium bomber (two 840-hp. Mercury VIIIs, top speed with full load 279 m.p.h. at 15,000 ft., climb to 15,000 ft. with full load 8.8 minutes). Long description, specifications, performance, cutaway drawing. Aeroplane, June 16, 1937, page 734, 4 illus.

Building the Battle. Fairey Battle medium bomber is powered by a Rolls Royce Merlin I glycol-cooled vee-twelve engine (rated at 990 hp. at 12,000 ft., maximum output 1050 hp., weight 1318.5 lb.). The bomber has a disposable load of 3968 lb. and range of 1000 miles. Armament and some construction details. Illustrations include views of the shops showing the airplane in production. Flight, June 17, 1937, pages 602a–602c, 7 illus.

Cards on the Table. Performance details are given in a short table for five new types of bombers for the R.A.F., namely the Vickers Wellesley general-purpose long-range bomber (925-hp. Bristol Pegasus XX), Fairey Battle medium bomber (1050-hp. Rolls Royce Merlin), Bristol Blenheim medium bomber (two 850-hp. Bristol Mercury VIIIs), Handley-Page Harrow heavy bomber (two 960-hp. Bristol Pegasus Xs), and Armstrong-Whitworth Whitley heavy bomber (two 880-hp. Armstrong-Siddeley Tiger IXs). Photographs of Vickers Wellesley and Fairey P4/34 appear on preceding pages. Aeroplane, June 16, 1937, pages 718, 715–717, 3 illus., 1 table.

Five of the Finest. Armament performance, and design details of the following: Bristol Blenheim medium bomber (two Mercury VIII radials rated at 825 hp. at 13,000 ft. maximum speed 280 m.p.h. at 15,000 ft., rate of climb 15,000 ft. in 8.8 min., service ceiling 30,000 ft.); Fairey Battle medium bomber (Rolls Royce Merlin rated at 990 hp. at 12,000 ft., maximum speed 257 m.p.h., disposable load 3968 lb.); Handley-Page Harrow II heavy bomber (two Pegasus XX fully-supercharged engines giving 835 hp. at 8500 ft., maximum speed 200 m.p.h., at 10,000 ft., maximum range 1840 miles); Armstrong-Whitworth Whitley heavy bomber (three forms, one with Tiger IX 790 hp. engines, and others with Tiger VIII engines with two-speed supercharger); and the Vickers Wellesley general-purpose and bombing airplane said to do 202.5 m.p.h. at 8000 ft. and 191.3 m.p.h. at 2000 ft. with a supercharged Pegasus XX engine. Long article and editorial. Flight, June 17, 1937, pages 592–595, 590, 9 illus.

"New and Experimental." Nine experimental types to be shown at Hendon, including: Gloster F.5/34 single-seater fighter (840-hp. Mercury); Fairey P.4/34 light bomber (Rolls-Royce Merlin 990/1050-hp.); Hawker Henley P.4/34 light bomber (Rolls-Royce Merlin 990/1050-hp.); Blackburn fleet fighter dive bomber (Bristol Mercury); Miles P. V. advanced trainer (Rolls-Royce fully supercharged Kestrel XVI); DeHavilland Don advanced trainer; Airspeed Oxford advanced trainer (two Armstrong-Siddeley Cheetahs); Airspeed radio-controlled Queen Wasp; and the De-Havilland Albatross transatlantic transport (four Gipsy Twelves; cruising speed 200 m.p.h.). Few details of some of the above airplanes. Flight, June 24, 1937, pages 626–628, 7 illus.

New R.A.F. Bombing Machines. Latest types of bombers now in use in the R.A.F. including: Bristol Blenheim (two 825-hp. Mercury engines, top speed 279 m.p.h. 14,000 ft.); Fairey Battle (1050-hp. Rolls Royce Merlin, top speed 257 m.p.h. at 15,000 ft., range of about 1000 miles); Armstrong-Whitworth Whitley (two 800-hp. Armstrong-Siddeley Tigers, top speed 192 m.p.h., range 1500 miles); Handley-Page Harrow (two Bristol Pegasus, top speed 190 m.p.h. at 8000 ft.). Few details. Engineer, June 25,1937, page 729.

Round the Fairey Workshops at Stockport. P. Masefield. Method of producing the Fairey Battle Airplane and a few details of the Battle are referred to in a general account of a company celebration. This is preceded by an article by C. G. Grey entitled "On the Right Road to Expansion," and reviewing the development of the company. Aeroplane, June 16, 1937, pages 728–730 and 725–727, 10 illus.

Our National Aero Show. Airplanes, engines, materials, parts and accessories to be exhibited at the Society of British Aircraft Constructors' Show are listed. Aeroplane, June 23, 1937, pages 779–780. Flight, June 24 1937, pages 619–620.

Short Spans. Short Brothers are designing an 80,000-lb. flying boat with 180-m.p.h. cruising speed for transatlantic operation, according to reports. Brief reference. Western Flying, July, 1937, page 34.

Up in the Blenheim. H. A. Taylor. A civilian pilot's impressions of the Bristol Blenheim bomber. Long description with two-page cutaway drawing showing location of equipment, photograph giving plan view of the control cabin, and other illustrations. Flight, June 24, 1937, pages 621–625, 6 illus.

Photographs Only. Fairey P.4/34 (1050-hp. Rolls Royce Merlin) built to a different Air Ministry specification from the Fairey Battle. One photograph demonstrates the retractable undercarriage and flaps. Aeroplane, June 16, 1937, pages 715–716, 2 illus.

New Gloster F.5/34 single-seat fighter (840-hp. Bristol Mercury engine). Dimensions and reference to backwards retracting alighting gear and controllable-gilled cowling. Aeroplane, June 16, 1937, page 732, 1 illus.

Gloster Gauntlet single-seater day-and-night fighter, Hawker Fury Mk. II, Hawker Hector army cooperation, Hawker Hind light bomber, and Avro Anson general reconnaissance airplanes. Flight, June 24, 1937, page 647, 5 illus.

Fairey Battle medium bomber (1050-hp. Rolls Royce Merlin engine, maximum speed 257 m.p.h. at 15,000 ft., range about 1000 miles at gross weight of 10,775 lb. with full military load), **Armstrong Whitworth Whitley** heavy bomber (two 800-hp. Armstrong Siddeley Tiger engines, maximum speed 192 m.p.h. at 7000 ft., range 1500 miles at gross weight of 21,098 lb. with full military load), **Handley-Page Harrow** heavy bomber (two 820-hp. Bristol Pegasus engines, maximum speed 163 m.p.h. at 15,000 ft., range 1250 miles at gross weight of 23,500 lb. with full military load), and the **Bristol Blenheim** medium bomber (two 825-hp. Mercury engines, maximum speed 279 m.p.h. at 14,000 ft., range about 1000 miles at gross weight of 11,776 lb. with full military load). Photographs and drawings, some of them cut away to show construction. Aircraft Engineering, July, 1937, pages 182, 187–189, 16 illus.

High-Altitude Flying Record. Height of 53,937 ft. was reached by Flight-Lieutenant M. J. Adam of the Royal Aircraft Establishment on June 30 in a Bristol 138 single-seater high-altitude monoplane fitted with a special Bristol Pegasus engine. Ascent occupied 1 hour 35 minutes. Brief note. Engineering, July 9, 1937, page 47. Engineer, July 9, 1937, page 31.

HOLLAND

The Fokker G-1. Two-engined airplane for attack, reconnaissance and light bombing. Dimensions and performance when powered by two Bristol Mercury VII engines. L'Aérophile, May, 1937, page 98, 1 illus.

ITALY

Macchi C-94 Amphibian. Italian light transport amphibian powered by two Wright Cyclone SGRF-52 engines. Construction, characteristics, and performance with a useful load of 2000 kg. Speed at 1000 meters is 286 km. per hour. L'Aérophile, May, 1937, page 100, 3 illus., 1 table.

Records to Italy. Altitude record of 51,348 ft. made by Lt. Colonel M. Pezzi in the Caproni 161 powered by a Piaggio P.XI RC-72 14-cylinder radial, and the speed-with-load records of the Macchi M.C.94 12-passenger amphibian monoplane and the Cant. Z. 508 three-engined seaplane. Brief references. Aviation, July, 1937, page 51.

The Ten Records of Mario Stoppani. Records made with a Cant. Z-506 seaplane on May 27. Brief note. Les Ailes, June 3, 1937, page 12.

With Foreign Builders. Italian P-32 Piaggio twin-engined bomber going into production this year is made almost entirely of wood. The bomber is powered by two Isotta Fraschini Asso XIRC 812-hp. engines and has a maximum speed of 249 m.p.h. at 16,404 ft. Specifications and very few details. Comments also on the use of wooden construction and a questionable mixture of Somali cotton and Japanese silk for Italian airplanes. Aviation, July, 1937, page 41.

1000-Kilometer Speed Record Made in Italy. Flying with Lt. Col. A. Bisco, Bruno Mussolini set a world speed record for 1000 km. in a trimotored Savoia-Marchetti S-79 bomber carrying a load of 2000 kg. at an average speed of 211.8 m.p.h. Brief reference. Aero Digest, August, 1937, page 66.

Breda 64 Two-Place Pursuit. Low-wing pursuit powered by a Piaggio-Stella IX 610-hp. engine has a maximum speed of 360 km./hr. Construction, characteristics, and performance. Weight, bomb load and the guns assigned to pilot and gunner are given for the plane when equipped as a two-place pursuit, reconnaissance, and high-speed bomber, respectively. Brief note. Rev. de l'Armée de l'Air, May, 1937, pages 587–588, 1 illus., 1 table.

A New Championship in Altitude: 15,655 Meters. Caproni Ca-161 with which Colonel Pezzi made a high-altitude record of 15,655 meters. Details of flight, airplane, Piaggio P.XI.R.C. 72 engine, and equipment. L'Aerotecnica, May, 1937, pages 472–475, 2 illus.

JAPAN

Foreign News in Brief. Japanese-built low-wing stressed-skin monoplane having a nonstop range of 10,000 miles and wing span of 91.8 ft. The airplane will be powered by a 800-hp. Prestone-cooled Kawasaki engine. Few details. Aero Digest, July, 1937, pages 123–124, 1 illus.

RUMANIA

With Foreign Builders. SET-XV single-seater pursuit sesquiplane developed for the Rumanian Government and modelled after various French fighter types. The plane has a SET wooden propeller, Gnôme Rhône engine developing 500 hp. at 12,139 ft., and a maximum speed of 211 m.p.h. at 13,123 ft. Description and specifications. Aviation, July, 1937, page 40, 1 illus.

U. S. A.

Equipment for Douglas DC-4. Goodrich tires 65 in. in diameter and Pratt and Whitney Twin Hornet 1400-hp. engines. Few details. Aero Digest, July, 1937, page 70, 1 illus.

The Four Winds. Designs have been prepared for a Curtiss single-seater to be fitted with the 1000-hp. Allison glycol-cooled vee-twelve engine which passed the 150-hour type test demanded by the U. S. Army Air Corps. Brief reference. Flight, June 17, 1937, page 579.

Grumman Model G-21 Amphibian. Grumman 6–7 place twin-engined 205-m.p.h. all-metal high-wing hull-type amphibian for commercial and private use is powered by two Pratt and Whitney Wasp, Jr. SB-450-hp. engines. Very long description of design, construction, equipment, specifications, and full-load performance. Aero Digest, July, 1937, pages 64–66, 10 illus., 1 table.

Details, characteristics, performance. Aviation, July, 1937, pages 36–37, 7 illus., 1 table.

Jones S-125 Refinements. Improvements in the two-place sport monoplane. No specification given. Aviation, July, 1937, page 35, 5 illus.

Lockheed's Model 14. H. L. Hibbard. Development of the Model 14 twin-engined transport which has a maximum speed of 264 m.p.h. at 8700 ft. and a maximum range of 1900 miles with full load. Factors used to obtain high speed are discussed. Development described includes: wind-tunnel work, full-scale testing of sample structures (such as a full-size wing section with Fowler flap, the integral fuel tanks, and complete fuselage section with and without window and door cutouts), flight tests of landing gear, and structural materials and fabricating methods. Aviation, July, 1937, pages 32–34, 75, 8 illus.

Metal for the Light Plane. J. P. Eames. Metal construction in the Aeroneer and Ryan ST airplanes, and the Fleetwing amphibian. Continued. Western Flying, July, 1937, pages 22–23, 1 illus.

A Stratospheric Lockheed Electra. Experimental plane of the Army Air Corps having a pressure cabin, and two Pratt and Whitney Wasp 450-hp. engines with turbo supercharger which permits power to be recovered at 10,000 meters because each engine is furnished also with an ordinary supercharger. Photograph only. Les Ailes, June 3, 1937, page 11, 1 illus.

U. S. S. R.

Four Seaplane Records Made in the U. S. S. R. Records made by Pilot Pissmenny with the AIR-6 seaplane with a M-11 engine, and a record made by Polina Ossipenko. Brief note. Les Ailes, June 3, 1937, page 12.

With the Foreign Builders. Soviet LBM-2, designed for freight carriage over relatively short distances is a flying wing, entirely devoid of fuselage, which both glides and utilizes the 100-hp. M-11 engine. It is intended to fly at 73 m.p.h., and has a range of 6 hours, and span of 90 ft. Freight compartments have a capacity of 2205 lb. Very few details. Aviation, July, 1937, page 41.

Bomber Deliveries. Non-stop night flight of the YB-17 bomber from March Field to Langley Field covering 2450 miles in 12 hours 50 minutes. Very brief reference and photograph of the XB-15 being assembled in the Boeing plant. Aero Digest, August, 1937, page 72, 1 illus.

Consolidated Long-Range Commercial Flying Boat. Consolidated PBY-1 twin-engined flying boat designed for military use as a long-range patrol bomber and for commercial use as a long-range transport or cargo flying boat. Commercial version designed for R. Archbold is powered by two 1000-hp. Twin Wasp engines and has a cruising speed of 145 m.p.h. and range of 4000 miles. Long description of design, structure, and equipment of the commercial version with references to the military type. Aero Digest, August, 1937, pages 36, 38, 83, 4 illus.

Contract. Curtiss P-36 pursuit airplane, 230 of which have been ordered by the War Department will be powered by a 1100-hp. radial engine and will be capable of more than 300 m.p.h. Photograph only. Automotive Industries, July 24, 1937, page 110, 1 illus.

Military Aviation. Consolidated P-30 powered by a Curtiss Super-Conqueror SV-1570 675/705-hp. engine. Characteristics, performance, armament and photograph. Photograph of the Boeing YB-17. L'Aérophile, June, 1937, page 125, 2 illus.

Seversky Plant Busy. Seversky new dive bomber which proved its ability to stand a 15,000-ft. power dive at more than 500 m.p.h., and speed record of Major de Seversky who averaged 340 m.p.h. in his Demonstrator are briefly referred to. U.S. Air Services, July, 1937, page 21.

The Twin-Engined Bell XFM-1 Army Fighter. Bell XFM-1 twin-engined pusher-type monoplane now undergoing initial flight tests for the U. S. Army Air Corps. Airplane carries a crew of five, six guns and a load of light bombs and is expected to do over 300 m.p.h. Wing gunners sit in cockpits in the leading edge of the wing and can travel between their stations and the fuselage while in flight. Long description and references to the two Allison chemically-cooled engines, oxygen supply for the crew, and auxiliary power plant. Aero Digest, August, 1937, page 25, 3 illus.

Record-Breaking Long-Range Russian Monoplane ANT-25. Russian ANT-25 monoplane which established a non-stop flight record of 6262 miles over the North Pole. The airplane has a wing span of 112 ft. and is powered with a M-34R 12-cylinder V-type liquid-cooled engine developing 950 hp. at 1950 r.p.m. Fuel consumption is 0.47 lb./hp.-hr. Rubberized bags are located in the wings and fore portion of the fuselage. Long description of construction, electrical installation, and specifications. Aero Digest, August, 1937, pages 32 and 34, 6 illus.

Air Transportation

D. L. H.'s New Floating Base. New motor ship Friesenland of Deutsche Lufthansa intended as a base for aircraft operating in the North Atlantic. Few details. Flight, June 24, 1937, page 636.

Transatlantic Air Services. "The flights, though made in opposite directions and in different wind conditions, have apparently borne out the general view that the short boat 'Caledonia' is appreciably faster than its American counterpart." Editorial on transatlantic payload problems, referring to recent transatlantic flights made by Pan American and Imperial Airways flying boats, results obtained, fuel consumption of the Pegasus engines used, and remarks of Mr. Gouge of Short Brothers on speed and load of the Empire boats. Engineer, July 16, 1937, page 75.

Records

Records. Record flights, during the month of May, including those made by Italian, Russian and other pilots. L'Aérophile, June, 1937, pages 141–142, 1 illus.

Propellers

Offset Propeller Raises Performance. "Flight tests of the Maynard-DiCesare propellers have indicated increased cruising speeds, reduced vibration, lower engine temperatures, and a 10% jump in airspeed and climb." Arc blades of the propeller are said to incur a larger air stream by a larger bite of air, this air stream leaving the blades at a sharp bias and being directed under the plane. Brief note. Aero Digest, August, 1937, page 58, 1 illus.

Propellers for the Hindenburg Airship. M. Schirmer. Development of propellers for the Hindenburg, especially wind-tunnel tests of models. Luftfahrtforschung, June 20, 1937, pages 293–299, 13 illus., 1 table.

The Vibration of Airscrew Blades. Major B. C. Carter. Disturbed motion on a stationary metal propeller was studied by means of a modified unit, and vibratory motion of rotating blades by means of a special technique

developed at the Royal Aircraft Establishment. Editorial quoting part of paper presented before the Royal Aeronautical Society. Engineering, July 16, 1937, pages 75–76.

Lycoming Electric Propeller Control. Model P-220 Lycoming controllable-pitch propeller with new electric control and engine throttle integral, now available as standard equipment for Wright Whirlwind engines as well as for all models of the Lycoming R-680 engine. Short description and installation diagram. Aero Digest, July, 1937, page 73, 2 illus.

Pulling Their Weight. Six sizes of deHavilland propellers. Weight, diameter, horsepower of engine for which each size is adapted, and cost. Brief note. Aeroplane, June 23, 1937, page 781.

Recording Vibrational Strains in Structural Members. C. K. Graveley. Method of measuring vibrational and fluctuating strains in propellers by use of a Rochelle salt crystal, the generated voltage of which is proportional to pressure or strain. Precautions necessary for accurate measurement, choice of crystal, and two types of crystal used for measuring torsional and bending strains in the propeller. Aero Digest, July, 1937, page 50, 2 illus.

Equipment

At the "Static" Show. Components, accessories, and materials to be exhibited by nearly a hundred firms at the Society of British Aircraft Constructors show are listed including engine components, propellers, undercarriages, instruments and controls, electrical equipment, airport equipment, radio, dopes, window materials, plastics, fuels, oils, dispensing equipment, metals, and other materials. Flight, June 24, 1937, pages 648–656, 8 illus.

Aircraft Instruments

Finding Your Way in the Air. Lt. Comdr. P. V. H. Weems. Aperiodic magnetic compasses, compass errors due to magnetic variation and deviation, acceleration and turning, practical compensation, and other compasses. Continued. Aviation, July, 1937, pages 22–23, 68, 71, 3 illus.

Little Emil Comes to Town. Askania aircraft instruments, including the Little Emil distant-reading compass, and electrically-heated pitot head. Few details and references to other Askania products. Brief. Aeroplane, June 23, 1937, page 782.

Behavior of Static Pressure Meters at High Speeds. H. Danielzig. For accurate measurement at airplane speeds up to 400 km./hr. a tube length of 20 to 24 meters was found to be sufficient in order to locate the trailing device at a minimum distance of 6 meters below the fuselage. The pressure element is an all-metal tube 7 mm. in diameter and 4 mm. inside diameter, and is located in a trailing device which has an overall length of 625 mm. and weight of 6.5 kg. Development of the static pressure meter, and test results are discussed and nomographs developed for ascertaining tube form for the device are given. The meter was tested with the Heinkel He-70 airplane. A tube form for an airplane speed of 600 km./hr. has also been constructed. DVL report. Luftfahrtforschung, June 20, 1937, pages 304–309, 12 illus., 14 equations.

Evaluation of Error in Dynamic Pressure Calibrations Made by Means of Meters Trailing below the Airplane. G. Kiel. Disturbance from the wing, at the location of the trailing meter below the airplane is estimated in order to determine the accuracy of dynamic pressure calibrations made in flight with this device. Static meters developed by the DVL were used in the examples given. Diagrams are presented from which the accuracy of the dynamic pressure calibration can be read. DVL report. Luftfahrtforschung, June 20, 1937, pages 310–313.

Navigation Equipment of the ANT-25. Lt. Commr. L. R. Gray. Layout of equipment, and details of the sun compass used in conjunction with a directional gyro, bubble sextants, Wittnauer 8-day watches, ground speed and drift meter, books of 2-star altitude curves, maps, and radio equipment. Aero Digest, August, 1937, pages 34, 62, 2 illus.

The Regulation of Compasses in Flight. J. Hartog and M. Boel. Problems of aerial navigation, and details of the Salmoiraghi drift indicator, and its use in regulating the compass in flight. Examples are worked out for regulation in single-engined, two-engined and three-engined airplanes, respectively. Curves show the deviations of a compass following compensation on the ground, and deviations of the same compass in flight. L'Aéronautique, Supplement, April, 1937, pages 49–54, 6 illus., 4 equations.

Sonic Altimeter. Delay between sending of high-intensity sound from an airplane and receiving it after reflection from the ground is indicated directly on a meter in equipment developed by Lt. L. P. Delsasso. Photograph only. Electronics, July, 1937, page 28, 1 illus.

Tube "Repeats" Aircraft Compass Bearings. Electronic telemetering applied to navigation of aircraft. Readings of a magnetic compass are transferred electrically to a meter mounted in front of the pilot. Operation is similar to that of the homing compass except that the direction is controlled by a simple magnetic compass instead of by an incoming radio wave. Description of device developed by F. West. Electronics, July, 1937, page 28.

Aircraft Radio

Aero Radio Digest. R.C.5 automatic radio compass developed by Le Materiel Telephonique, Paris, to be marketed in this country. Heintz and Kaufmann Type 168 remotely-controlled motor-driven antenna reel. Bureau of Standards radio meteorograph for accurate measurement of cloud densities and altitudes. Two-way radiophone equipment to furnish telephone service to passengers in flight, and to be standard equipment on the new Northwest fleet of Lockheed Zephyrs. Short descriptions of all but the last, and a reference to installation of Lorenz instrument-landing indicators and receivers on new Link trainers built for the British Air Ministry. Aero Digest, July, 1937, pages 56, 58, 4 illus.

Beams in Australia. New application of short-wave directional radio adopted by the Australian government after thorough tests. New feature consists in the projected use of an ultra-short-wave Lorenz beam for long-distance navigation instead of merely for the final blind approach to the airport, as in Europe. Most stringent tests were made on night effect, sunrise effect, and wandering of the beam. None of these phenomena was detected in this ultra short-wave beam and even over the mountain ranges there was no tendency to split. Aeroplane, June 16, 1937, page 736.

Direction Finder. Learadio R-3 receiver and loop employing a "magic eye" indicator. Few details. Aviation, July, 1937, page 44, 1 illus.

Flying the Radio Ranges. H. W. Roberts. Radio range beacons, and beacon and receiver vagaries. Course shifting, bending of range courses, phenomenon of multiple courses, effect of antenna design and its location on the airplane upon the indicated signal, especially upon reception of the cone of silence phenomena, the relation between signal level and topography of the terrain over which the airplane passes, and phenomenon of apparent signal reversal. Aero Digest, July, 1937, pages 52, 55, 58, 8 illus.

IL at ID. D. G. Fink. Lorenz instrument-landing system installed at Indianapolis, method of operation, recent demonstration, and comparison with other I-L systems. Long description. Aviation, July, 1937, pages 20–21, 72, 75, 3 illus.

New Radio Facility Developed. Western Electric band-pass filter making possible dual broadcast on the same frequency. Few details. Western Flying, July, 1937, pages 36, 38.

Aero Radio Digest. Bendix aircraft radio direction finders, the camera obscura and two-way radio apparatus developed by the U. S. Army Air Corps for use in bombardment training and practice, and the improvements made by the Bureau of Standards for instrument landing, consisting of modification of the glide path transmitting antenna array are discussed in detail. A warning on moisture condensation in aircraft radio apparatus, issued by the Aero Insurance Underwriters is also included. Aero Digest, August, 1937, pages 42, 44, 10 illus.

Research in Static. H. W. Roberts. More accurate conception of snow static production, basis knowledge on forecasting such conditions, and basic means of elimination of its effects by navigation and special antennas. Research carried on by United Air Lines in cooperation with a number of scientists and results obtained are described. Tests are now in progress with a series of 17 3-ft. 0.003-in.-diameter trailing wires attached to points on wings and tail surfaces. Aero Digest, August, 1937, pages 26–27, 83, 3 illus.

The New Valoris Radio Beacon Constantly Giving Position in Flight. System based on the measure of relative intensity of the reception from three transmitters stabilized in regard to power and frequency. Long description of principles involved and application to navigation. Les Ailes, July 1, 1937, page 8, 4 illus.

Test on the Utilization of Radiotelegraphy in the Armée de l'Air. Capt. R. Luce-Catinot. Services to be expected from radio in regard to control, weather reports, navigation and landing, rules for use of the network and for collective transmission, and the problems of instruction and control. Rev. de l'Armée de l'Air, May, 1937, pages 509–519.

Lightning. B. L. Goodlet. In nine out of ten known cases of British airplanes being damaged by lightning, the radio aerial was hanging down and damaged. Damage to aircraft is mentioned in a long article on lightning as a physical phenomenon, and effects of lightning strokes to overhead transmission lines. Jour. Instn. Electrical Engrs., July, 1937, pages 1–26 and (disc). 26–56, 13 illus., 8 tables, 62 equations.

Institute News and Radio Notes. "Features and Theory of Operation of an Aircraft Radio Compass, the Functions of its Control and its Operational Characteristics," E. D. Blodgett of the RCA Manufacturing Company. Aircraft compass designed for use of itinerant or private fliers. Very brief abstract of paper presented before the Philadelphia Section. Proc. Inst. Radio Engrs., July, 1937, pages 801–802.

New Static Discovery. Atmospheric static heard in the pilot's earphones is caused by discharge from the trailing edges of the wings and tail surfaces of the static already gathered from certain cloud formations, according to results of research undertaken by United Air Lines in their flying laboratory. Few details of research. Western Flying, July, 1937, pages 32, 40.

R.C.A.'s Miniature Radio. AVR-10 and AVR-10-A receiver weighs 8.5 lb. and is designed especially for Class I aircraft, and as an auxiliary receiver for other classes of craft. Few details. Western Flying, July, 1937, page 38, 1 illus.

Radio and the Private Pilot. C. L. Moser. New Federal regulations governing intentional instrument flying, requirements for the radiotelephone operator's license, and advantages of the radio equipped plane. Western Flying, July, 1937, pages 12–15, 40, 3 illus.

Radio Laboratries in Flight. Flying laboratory of United Air Lines. Very few details. Scientific American, July, 1937, page 53, 2 illus.

Blind Landing. Lorenz-IT&T blind landing system installed at Indianapolis airport recently demonstrated its ability to bring aircraft to safe landings through the most difficult weather conditions. Details of equipment and operation. Electronics, July, 1937, pages 26–27, 11 illus.

Airport Equipment

Bituminous Mixing Machine. Ransome mixer for handling hot and cold patch mixtures used to maintain and surface concrete runways. Few details. Aero Digest, July, 1937, page 70.

Air Depots Ten Years Ago and Today. J. S. Wynne. Reference to the airport oscillating beacon at Wright Field, and a few details of the new British Transatlantic Air Terminal at Benton, Newfoundland, are included in a general discussion of improvements of airports in this country. U.S Air Services, July, 1937, pages 17–18, 31.

Maximum Utilization of Two Runways. H. L-M. Knight. Method for determining the direction of the second runway from known aeronautical, meteorological and engineering data. Aero. Digest, August, 1937, pages 40, 83, 2 illus.

Field Light Panel. Westinghouse control panel for airport lighting. Few details. Aviation, July, 1937, page 44, 1 illus.

Miscellaneous Equipment

Acoustical Bearing of Aircraft—Methods and Modern Equipment. P. Leglise. Possible methods of locating invisible aircraft by means of infrared or calorific rays, from magnetic waves of the ignition circuit, and by acoustical waves are considered. Acoustical methods of locating aircraft from the direction of machine-gun fire, aiming of searchlights in night pursuit, and direction of fire of cannons are discussed. Principles of the biauricular listening device are taken up, the Goerz bistatic and the Barbier, Bénard and Turenne monostatic methods are described in detail, and corrections given for temperature and wind. Paper presented before the Associazione di Aerotecnica, 1935. L'Aerotecnica, April, 1937, pages 287–316, 25 illus., many equations.

Balance Computer. Librascope balance computer mechanically adds and balances all loads applied to a transport airplane and gives the operator an instant reading showing the gross weight. The computer may also be carried in the plane to provide a constant check on c.g. location. The type described is manufactured for the Lockheed Model 14, its weight being between 3 and 5 lb. It is separately designed for each type of airplane. Aviation, July, 1937, pages 43–44.

Float-on-Air—and Water. New safety seats being fitted to the Short flying boats for Imperial Airways Empire routes. Few details. Flight, June 17, 1937, page 603, 2 illus.

Parachutes

Technical Note. In order to land at the North Pole the A.N.T.6 bomber is being equipped with a parachute placed at the rear of the fuselage and joined by cables to the central section of the wing. When the skiis touch the ground the parachute is unstrapped by the pilot. Brief reference. Les Ailes, July 1, 1937, page 6.

Meteorology

Aircraft Icing Zones on the Oakland-Cheyenne Airway. J. A. Reilly. Icing conditions occurring along moving fronts that separate different air masses and along high mountain ranges, and particular difficulties in flying over this airway. Forecasts, classification of ice, icing conditions along warm fronts, cold fronts and cold-air mass clouds, and the attendant circumstances including static and winds. Monthly Weather Rev., March, 1937, pages 104–108, 4 illus.

Meteorological Equipment

Fog Finder Warns Fliers of Low Visibility Ahead. New fog indicator, the anathermoscope, used by Weather Bureau in making special forecasts for fliers. Short explanation. Bul. Am. Meteorological Soc., April–May, 1937, page 181.

Engine Design and Research

British Developing Two-Stroke Diesel for Aircraft. New type of sleeve valve not requiring sealing rings, and a new two-stroke Diesel engine capable of running at speeds up to 2500 r.p.m. Ricardo and Company have built the engine for the Air Ministry to determine the practicability of higher speeds. They have shown that no difficulty is likely to be encountered in starting and idling with a compression ratio as low as 9:1 if a high-compression supercharger is fitted. Automotive Industries, July 24, 1937, page 128.

Determination of Radiator Drag and Amount of Fluid Flowing Through Radiators Mounted in Various Positions. W. Barth. Air resistance and fluid flow through airplane-engine radiators are determined mathematically. Relations between transmission of the cooling elements, front cooling surface, mounting arrangement, and drag are explained. Report of Dornier Metallbauten G.m.b.H. Luftfahrtforschung, June 20, 1937, pages 300–303, 4 illus., 1 table.

M.I.T. Laboratory. H. E. Blank, Jr. Indicator method of measuring friction horsepower, effect of variation in inlet and exhaust pressures upon both pumping and mechanical friction, effect of port shape and timing on scavenging efficiency of a two-cycle cylinder (research for the N.A.C.A.) and new method of measuring scavenging efficiency, and the effect which sound waves impressed on a combustible gaseous mixture have on rate of combustion of the mixture. M.I.T. research on engine problems, special testing equipment developed, and results obtained are outlined. Machine for converting pressure-time indicator diagrams to pressure-volume basis and other interesting test apparatus are illustrated. Automotive Industries, July 24, 1937, pages 114–116, 127, 128, 5 illus.

Piston-Pin Design. P. M. Holdt. Dimensions of piston pins for high-speed Diesel engines are calculated by a new method which takes account of cylinder bore and maximum combustion pressure. Method described by Ensslin in VDI, March 27, is adapted to English units of measurement. Automotive Industries, July 24, 1937, page 113, 1 illus.

Shock Absorbing Mounting of Engines in Automobiles and Airplanes. B. Riediger. By setting up equations for forced vibrations, and by introduction of proportional values, it is shown how the buffer for the spring mounting of engines can be calculated. Calculations are not subject to limitations of any kind relative to engine size. V.D.I., June 19, 1937, pages 717–720, 12 illus., 2 tables, 52 equations.

The Characteristics of Engines of Kadenacy Design. S. J. Davies. Kadenacy contributions to engine design and test results obtained. First article deals with interactions between gases which leave the cylinder during an exhaust period and gases which, at the instant of opening the exhaust port, occupied the pipe. Eight tests are described.

Second article describes a ninth test, points out the remarkable increase in volumetric efficiency with increase of b.m.e.p., and compares it with that of the Junkers engine. Inventions have been adopted by Armstrong Whitworth Securities Company. Engineering, June 18 and 25, 1937, pages 685–688 and 715, 16 illus., 1 table.

The "Equi-Comprime" Aircraft Engine. L. De Monge. Engine with variable volume ratio which was tested by the author, and a variable-compression aircraft engine developed by Damblanc in 1920 are discussed and illustrated in the last part of the article. Long equations from papers presented at the International Aeronautical Engineering Conference by Bonnier (theoretical and indicated engine efficiencies and supercharging), by Boerlage, and by Racine are given in the first part. Situation of the aircraft engine in regard to volume ratio of compression and volumetric efficiency is reviewed. La Technique Aéronautique, No. 143, 1937, pages 45–61, 11 illus., 2 tables.

More Horses in the Air. R. M. Cleveland. Developments in aircraft engines, propellers, reduction of vibration, and fuels are reviewed. Factors in design of high-horsepower spark-ignition aircraft engines are listed with the comment that heavy-oil aircraft engines probably will not be developed in this country to compete with them. Scientific American, July, 1937, pages 14–17, 10 illus.

Engine Bearings

Lead Bronzes. W. Claus. Mechanical properties and applications of a wide range of lead bronzes, solid bearings of lead bronze, and bi-metal bearings of lead bronze supported by a shell of steel to which it is bonded. Latter types are discussed in detail, and their longer life in engines, as shown in engines of the Hindenburg airship, are referred to. Conservation of copper and tin in Germany also mentioned. Abstract from Metallwirtschaft January 29. Engineer, Metallurgist Sup., June 25, 1937, pages 33–35, 1 table.

Engines

Bristol Motors Output. Type-tested performance figures for the newest Bristol aircraft engine. Porseus 9-cylinder sleeve-valved (860/890 hp. at 2750 r.p.m. 7000 ft.), 14-cylinder sleeve-valved Hercules (1325/1375 hp. at 2750 r.p.m. at 4000 ft.), the Mercury IX and XII (890 hp. at 2750 r.p.m. at 6000 ft.), and the Pegasus XVIII with two-speed supercharger (900/940 hp. at 2600 r.p.m. at 6500 ft.). Aeroplane, June 23, 1937, page 748.

Engines at Hatfield. New *Alvis* Alcides two-row 18-cylinder (1700 hp. take-off power at 2250 r.p.m.), Pelides Major 14-cylinder (1000 hp. take-off power at 2400 r.p.m.). *Armstrong-Siddeley* Tiger VIII 14-cylinder two-row (920 hp. at 2375 r.p.m. for take-off). *Bristol* Mercury XI and XII (830 hp. at 2650 r.p.m. for take-off), Pegasus XVIII with two-speed supercharger (performance figures for medium and full supercharge ratios given), Perseus sleeve-valve medium-supercharged (785/815 hp. at 2650 r.p.m. for take-off), and Hercules 14-cylinder sleeve-valve, Britain's most powerful type-tested aero engine (1240/1290 hp. at 2650 r.p.m. for take-off). *Cirrus* Minor and Major. *De Havilland* Gipsy Major Series II, and Gipsy Six Series II. *Napier* Dagger E.108 H-shaped 24-cylinder. Pobjoy Niagara V. *Rolls Royce* Merlin vee-twelve glycol-cooled fully-supercharged (1050 hp. maximum output), and the Kestrel XVI fully-supercharged (745 hp. at 3000 r.p.m. at 14,500 ft.). Engines to be shown at the Society of British Aircraft Constructor's display. Leading characteristics and performance of the Alvis, Armstrong-Siddeley, and Bristol engines mentioned above are given with illustrations. Flight, June 24, 1937, pages 642–645, 10 illus.

Engines of the R. A. F. Armstrong-Siddeley, Bristol, Napier, Rolls Royce, and DeHavilland engines, and the military airplanes in which they are installed. A few details of the engines are given and their installation, cowling, and cooling in these airplanes are illustrated. A table presents leading data for thirty types of engines in service with the R.A.F. Flight June 24, 1937, pages 637–641, 13 illus., 1 table.

The Four Winds. Pratt and Whitney announce the Twin Hornet two-row 14-cylinder radial giving 1400 hp. for take-off on 95-octane fuel. Brief reference. Flight, June 17, 1937, page 597.

French Aircraft Engines. *Lorraine:* Petrel 12-Hfrs 720-hp. vee, Eider 12Q-OO 1050-hp. vee, Algol 9 NO[3] 450-hp. radial, Sirius 18F-00 1000-hp. radial, and Sterna 12R-00 810-hp. vee engines. *Potez:* 3B 70-hp. radial, 6Ba 150-hp. radial, 9E-00 and 9E-01 240-hp. radial, 9C-00 and 9C-01 250-hp. radial, 9Ab 225-hp. radial, and 12D-00 and 12D-01 485-hp. horizontally-opposed engines. *Regnier:* 4B-01 140-hp. inverted inline, 4D-02 60-hp. inverted inline, 4E-02 90-hp. inverted inline, 6B-01 180-hp. inverted inline, and 6C-01 250-hp. inverted inline engines. Construction, performance, reduction gear, supercharger, accessories, dimensions, weight, performance curves, photographs and drawings of these engines. La Technique Aéronautique, No. 143, 1937, pages 5–37, 80 illus.

Hirth Four-Cylinder Inverted Air-Cooled Aircraft Engine. German aircraft engine developing a maximum of 80 hp. at 2400 r.p.m. Three drawings and short description. Automotive Industries, June 26, 1937, pages 949–950, 3 illus.

A New Picture in an Old Setting. Three Napier-Culverin Diesel engines, built under license to the designs of the Junkers Jumo, are shown in a Blackburn Perth airplane. Attention is called to controllable gill cowling to regulate flow of cooling air through the radiators. Photographs only. Aeroplane, June 23, 1937, page 745, 2 illus.

A New Pobjoy Engine. Niagra V radial engine having a maximum of 130 hp. at 4400 r.p.m. New features incorporated, specifications and performance curves. Flight, June 17, 1937, page 605, 1 illus.

New Radial Diesel. Cylinder barrels are liquid cooled and heads air-cooled in the new Clerget 14-cylinder two-row radial Diesel for aircraft. The engine develops 450/500 hp. at 1800 r.p.m., weighs 1320 lbs., and has a fuel consumption of 0.396 per hp.-hr. Two different methods followed to reduce ignition delay, and metals used are briefly referred to. A double injection of gas oil has been used in bench and flight tests. Automotive Industries, July 17, 1937, pages 101–102.

Precision. H. E. Blank, Jr. Operations in the production of aircraft engines at the Pratt and Whitney plant. Long description. Automotive Industries, July 3, 1937, pages 10–19, 37, 20 illus., 3 tables.

What the Merlin Does. Rolls Royce Merlin 12-cylinder fully-supercharged aircraft engine has an international power rating of 990-hp. at 12,000 ft. Maximum output is 1050 hp. for take-off and dry weight 1318.5 lb. The engine has been designed for cooling by ethylene-glycol to work with a ducted radiator. Very few details. Aeroplane, June 16, 1937, page 731.

Air Ministry Official Notices. British aircraft engines approved for use of fuels containing tetraethyl lead. Precautions to be taken to prevent one kind of compressed gas being mistaken for another are also mentioned. Brief notes. Aircraft Engineering, July, 1937, page 195.

An Engine with Chemical Cooling: The 12-Cylinder 1000-hp. Allison. Long description. Les Ailes, July 1, 1937, page 8, 2 illus.

Pratt and Whitney Present Their New Twin Hornet Engine. Twin Hornet 14-cylinder two-row radial with a displacement of 2180 cu. in. and a take-off rating of 1400 hp. at 2500 r.p.m. using 95 octane fuel. Few details. U.S. Air Services, July, 1937, page 19, 1 illus.

Metals

Structure and Characteristics of Aluminium Alloys. H. C. Hall. First issue—Structure, casting properties, and physical strength after various heat treatments. Second—The R.R. series and V alloy are compared with high-magnesium, high-zinc, and high-silicon aluminum alloys. Section through a water-cooled *airplane-engine* cylinder shows working temperature at various points. Author is chief metallurgist, Rolls Royce, Ltd., and inventor of the R.R. series of high-duty aluminum alloys. Institute of British Foundrymen paper and discussion. Metal Industry, June 25 and July 2, 1937, pages 705–709 and 9–12 (disc.) 12–16, 21 illus., 4 tables.

British Standard Aircraft Specification. Specifications for "40" carbon steel, and for aluminum and aluminum-alloy tubes for *aircraft* purpose. Brief abstracts. Aircraft Engineering, July, 1937, page 193.

Light Metals. H. E. Blank, Jr. Advances made in manufacture and fabrication of aluminum and magnesium alloys, and in their application to automotive and aeronautical construction. Automotive Industries, July 17, 1937, pages 82–88, 11 illus.

Metallurgical Quality in Forgings. E. O. Dixon. Inspection procedures for detecting material unsuitable for *aircraft* parts, and improvements in quality brought about by forging. Aero Digest, July, 1937, pages 38, 40, 50, 3 illus.

Alloy Steels—Their Characteristics, Fabrication and Heat Treatment. H. C. Knerr. Physical properties of heat-treated alloy steels for *aircraft construction*, strength-weight factors, welded structures, endurance limits, fabrication and heat treatment, and quenching in oil. Aero Digest, July, 1937, pages 28–29, 1 illus., 1 table.

Non-Ferrous Metals in Aircraft Construction. Nonferrous metals used in the *aircraft* and components displayed by the Society of British Aircraft Constructors. Microstructure of the Stone wrought chromium-bronze bearing alloy illustrated. Metal Industry, July 2, 1937, pages 3–4, 3 illus.

Shrinkage Distortion in Welding—A Review of the Literature to January 1, 1937. W. Spraragen and G. E. Claussen. Shrinkage of oxyacetylene-welded *aircraft tubing* perpendicular to a rigidly clamped butt joint, found by Rechtlich, is given in a short section of this long review. Shrinkage perpendicular and parallel to the weld, angular distortion, and spacing allowance are considered for butt and fillet welds. Shrinkage distortion due to beads of weld metal, shrinkage distortion in structural welding, its theoretical aspects, and practical methods for avoiding welding distortion also reviewed. Correlated abstracts. Welding Jour., Weld. Res. Sup., July, 1937, pages 29–39, 10 illus., 15 tables, many equations.

Stress Distribution in Fillet Welds—A Review of the Literature to January 1, 1937. A. G. Solakian and G. E. Claussen. Elementary and empirical formulas for side and end fillets; experiments on stress distribution (extensometer, photoelastic, rubber-model, brittle-coating, and other methods, and fatigue tests); theory of elasticity applied to fillet welded joints; and fillet welds in bending. Correlated abstracts. Welding Jour., Weld. Res. Sup., May, 1937, pages 1–24, 26 illus., 11 tables, many equations.

Study and Control of Oxyacetylene Welding in Aeronautics. Colonel E. Zavattiero. Chemical composition of standard chrome-molybdenum steels used in the United States, Germany, and Italy, stresses due to welding, internal stresses, elimination of stresses, resistance to fatigue, and control and verification of welding, experimental results in heat treatment, fatigue tests, and magnetic and X-ray examinations. L'Aerotecnica, May, 1937, pages 415–442, 22 illus., 5 tables.

Fuels and Lubricants

German Fuel Regulations Revised. Gasoline without alcohol addition can be sold only for aviation purposes, and then only if a certificate has been issued by the German Air Minister. Brief note on changes requiring German producers to mix alcohol with all motor gasoline sold. Automotive Industries, June 26, 1937, page 941.

Fuel and Lubricant Testing

Four-Ball Top for Testing the Boundary Lubricating Properties of Oils Under High Mean Pressures. G. D. Boerlage and H. Blok. Boundary lubricating properties at pressures of 10,000 kg. per sq. cm. and higher, and at low sliding speeds of 0.1 cm. to 1 cm. per second were tested with the instrument described. Influence of temperature on friction coefficients for various oils tested is plotted in curves, and influence of combinations of different metals on boundary lubricating properties is also studied. Apparatus developed at the Delft Engine-Testing Laboratory, Royal Dutch Shell Company. Engineering, July 2, 1937, pages 1–2, 9 illus.

Methods of Testing Fuel Used in Aviation. A. Capetti. Methods of testing gasolines for stability, volatility, resistance to detonation, and mean effective pressure obtainable. Testing heavy-oil fuels, and the corrosion and deterioration of lubricants are also discussed. Engine tests of high-altitude conditions are considered briefly. Tables show results obtained in tests in the Fiat, Isotta-Fraschini and R. Politecnico Torino laboratories, and composition of Esso and "Elcosina," 1929 to 1936, also shown. L'Aerotecnica, February, 1937, pages 120–128, 3 tables.

Aeronautical Industry and Production

Manufacturers of Fabricated Parts and Aircraft Materials. Sources of supply of materials and fabricated parts for aircraft and aircraft engines Directory. Aero Digest, July, 1937, pages 86–121.

Expansion of Vultee's Manufacturing Facilities. Details of plant and new factory additions, and reference to Vultee attack bomber designed to utilize the drop hammer method in production. Bomber has maximum speed of 237 m.p.h., and cruising range of 2700 miles, and carries a bomb load of over 1100 pounds. Aero Digest, July, 1937, pages 24–26, 12 illus.

It Takes Factories to Build Airplanes. Additions of over 500,000 sq. ft. of factory space are being rushed by aircraft manufacturers, and over 1,000,000 sq. ft. of space have been added in the last six months. Survey of factory expansion for production of aircraft in the United States. Western Flying, July, 1937, pages 18–21, 14 illus.

Factory Expansions. Taylor-Young Airplane Company, St. Louis Airplane Division of Curtiss Wright Corp., Bendix Aviation Corporation, and Security Aircraft Corporation. Brief references to new additions planned or under way. Aero Digest, August, 1937, pages 74–75, 3 illus.

Factory Expansions. Taylor Aircraft Corporation, Kollsman Instrument Company, Glenn L. Martin Company and Douglas Aircraft Company factory expansion. Brief notes. Aero Digest, July, 1937, page 84.

Enemy Influences in the Aircraft Industry. Further Discussion on labor troubles in the British aircraft industry. Aeroplane, June 23, 1937, pages 766–767, 3 illus.

New factory opened by the Maynard-di Cesare Propeller Corporation, Elbert Manufacturing Company organized for manufacture of slow-speed high-torque fractional-horsepower electric motors and ignition systems, expansion of the Ethyl-Dow Chemical Company for production of ethyl fluid for gasoline, expansion of Solar Aircraft Company plant, license for Russian manufacture of Seversky amphibians, new factory of the Taylor Aircraft, and expansion of Security Aircraft Company plant. Very brief references. Aviation, July, 1937, pages 48–49, 55–56.

Deliveries Reach New Peak. First five month's figures in sales deliveries of aircraft. Brief note. Western Flying, July, 1937, page 34.

Air Forces

Favoured Nations. Blenheim medium bombers are being built by the Bristol Aeroplane Company for Turkey and Finland. Brief reference. Aeroplane, June 16, 1937, page 718.

Brazil

Short Spans. Stearman Aircraft Company has shipped the first six of its Brazilian order for 76-C3 advanced training and expeditionary planes. Brief reference. Western Flying, July, 1937, page 38, 1 illus.

Canada

Short Spans. Boeing Aircraft Company of Canada has received an order for 11 Blackburn Shark bombers as part of the rearmament program in Canada. Brief reference. Western Flying, July, 1937, page 36.

Foreign News in Brief. During the year ending February, 1937, Canada imported four Blackburn Shark II torpedo-spotter reconnaissance planes and six Westland Wapiti 11A day bombers. Five Stranraer flying boats have been ordered for the R.A.C.F. coastal patrol to be built by Canadian Vickers, Ltd., under special permission of the Supermarine Company. Brief references. Aero Digest, August, 1937, page 78.

France

With the Foreign Builders. The French Army is re-equipping all its observation captive balloons with an engine nacelle enabling them to move independently in the air. Brief reference to the Zodiac and Ridinger motorized balloons, photograph of the Potez 63 fighter airplane, and statement that Poland has a license to produce the Potez 63. Aviation, July, 1937, page 41, 1 illus.

Great Britain

Empire Air Defense. Major F. A. deV. Robertson. Strategical problems before the R.A.F. overseas, the six different commands organized overseas, and the requirements of mobility and reinforcement not necessary in the R.A.F. at home. Flight, June 24, 1937, pages 629–632, 6 illus.

Air Ministry Contracts. Orders placed by the British Air Ministry during April. List of companies and equipment but no mention of amounts ordered or prices paid. Aircraft Engineering, July, 1937, page 196.

Foreign News in Brief. Formation of five new squadrons has increased the strength of the British Metropolitan Air Force to 113 squadrons. Brief reference and few details of the new all-metal Gloster fighter. Aero Digest, July, 1937, page 123.

The Imperial Conference. Chapter on defense included in the Report of the Proceedings of the Conference, referring briefly to increased defense preparations being made in the Dominions. Aeroplane, June 23, 1937, page 746.

To Malta in an Aircraft Carrier. A. E. Barlow. Further account of the part played by the Fleet Air Arm and aircraft carriers in the British naval maneuvers off Gibraltar. Aeroplane, June 16, 1937, pages 721–724, 7 illus.

Joining the R. A. F. Regulations governing entry into the R.A.F., trades which can be followed, and technical training offered. Flight, June 24, 1937, pages 617–618, 3 illus.

The New Air Force. Major F. A. deV. Robertson. Framework of the new Royal Air Force describing the bomber, fighter, coastal and training commands. Flight, June 24, 1937, pages 612–616, 5 illus.

On the Why and Wherefore of Displays. C. G. Grey. Reasons for the R.A.F. Display, dangers of flying due to bad weather and collisions in the air, objections raised to the Display, stunts worth while, and big formations. Aeroplane, June 23, 1937, pages 761–764, 4 illus.

Royal Air Force Display. Short note on the Display, including a few details of the Queen Wasp radio-controlled airplane constructed by Airspeed, Ltd., and of the DeHavilland Albatross transatlantic mailplane. Engineering, July 2, 1937, page 17.

Squadrons at the Display. C. M. McAlery. Squadrons responsible for the major events. Brief historical review of ten squadrons and airplanes arming them. Aeroplane, June 23, 1937, pages 755–760, 11 illus.

Japan

Short Spans. Security Aircraft Corporation has obtained an order for six planes from the Japanese government. Brief reference. Western Flying, July, 1937, page 38.

Mexico

Foreign News in Brief. Strength of the First and Second Mexican air regiments is to be brought to 33 planes each this year and a third squadron of 33 planes is being considered. Brief reference. Aero Digest, August, 1937, page 79.

U. S. A.

Douglas Awarded Army Contract for 177 Bombers. Announcement by the War Department regarding contract for 177 Douglas 2-engined bombardment airplanes, and reference to Army Air Corps award of contract to Wright Aeronautical Corporation for 531 Wright Cyclone Model R 1820-45 engines. U.S. Air Services, July, 1937, page 21.

Phantom Wings of the Air Corps. Cy Caldwell. A Cy Caldwell analysis of present Air Corps strength and an argument for the necessity of a separate Air Corps. Aero Digest, July, 1937, pages 30, 34, 126, 127, 128.

U. S. S. R.

Seversky's Sale to Russia. Russia has placed an order for $780,000 with Seversky for two amphibians and manufacturing rights, and an option for two more airplanes together with complete tooling adequate for the production of these airplanes in Russia at the rate of ten a day. Brief reference. Western Flying, July, 1937, page 34.

Shrewd Buying. Russians have bought the license for the Consolidated long-range military flying boat and are negotiating with Sikorsky to buy construction rights for several types. Brief reference. Aeroplane, June 16, 1937, page 731.

Air Warfare

Air Ambulances for Spain. Protest against the British ban on export of air ambulances for use in the Spanish war. Brief editorial. Flight, June 17, 1937, page 591.

Bombing of the Deutschland. German Official Report regarding bombing of the German battleship by Spanish governmental planes, and subsequent shelling of Almeria by German naval forces. Quotation from "The Times." Aeroplane, June 16, 1937, page 716.

Information Obtained from the Spanish War. Difficulties arising in air warfare in Spain regarding the few direct hits made by airplane bombs, high landing speeds of modern pursuits, and range of fire from machine guns which the author considers should be replaced by cannons. Brief note on conclusions reached by a German officer. Abstract from "Die Weltwoche." Rev. de l'Armée de l'Air, May, 1937, page 585.